THE OHIO JOURNAL OF SCIENCE

VOLUME XXXII — 1932

HERBERT OSBORN, Editor

PUBLISHED AT COLUMBUS, OHIO, BY THE

OHIO STATE UNIVERSITY

and the

OHIO ACADEMY OF SCIENCE

THE OHIO JOURNAL OF SCIENCE

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THE OHIO JOURNAL OF SCIENCE

Is published jointly by the Ohio State University and the Ohio Academy of Science.

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THE TREATMENT OF OSTEOMYELITIS (INFECTION OF BONE) WITH FLY LARVÆ.*

DAVID F. MILLER, CHARLES A. DOAN
AND
E. HARLAND WILSON.

The disease known to medicine as osteomyelitis is an infection of the bone and adjacent tissues which frequently becomes chronic, often results in crippling deformities and sometimes proves fatal. The usual method of treatment is surgical, involving the removal of dead bone and the attempted elimination of infected areas. Because of the site and nature of the involvement, surgical treatment alone often fails and repeated operations are frequently required.

In 1917, during the World War, the late Dr. Wm. S. Baer of Baltimore, Md., serving with the American Army in France, noted that some of the soldiers brought to the hospital from the battle field with compound fractures of the thigh, had wounds heavily infested with maggots. Contrary to expectation, their general condition and that of the wounds seemed markedly better in contrast with others not showing such infestation. Furthermore, those with maggots seemed to recover in a shorter time (Baer, 1930). With these observations in mind, Dr. Baer returned to America and some ten years later decided to try the introduction of maggots into civil practice as a treatment in stubborn cases of osteomyelitis. His clinical studies were carried on for the most part at the Children's Hospital School in Baltimore.

The first treatments were made with maggots secured from natural sources. However, it soon became apparent that this was attended by certain dangers, inasmuch as fly larvæ in

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nature live along with microorganisms that are pathogenic to man. Therefore, the direct implantation of maggots by the surgeon in an open wound would be justified only after two important questions had been satisfactorily answered. (1) Do maggots assist in the process of healing? (2) Can they be released for activity without danger of inciting further disease complications? The first of these questions was at least suggestively answered in the affirmative by Dr. Baer's observations during the war and his preliminary peacetime studies. It then became necessary to seek a satisfactory answer to the second question. The rearing of bacterially sterile maggots is but one of the many problems which have been under study during recent months in several centers, notably at the Children's Hospital School in Baltimore, the United States Naval Medical School in Washington, D. C., and the Ohio State University, Columbus, Ohio.

A COOPERATIVE PROJECT.

For many years cultures of blowflies of various types have been grown in the Department of Zoology and Entomology at the Ohio State University for purposes of studying insect physiology, behavior and rearing methods. During the summer of 1930 one of us (D. F. M.) worked with the United States Bureau of Entomology at Washington, D. C., upon the problem of rearing flies for clinical use. Since October of that year the study has been continued at the Ohio State University as a cooperative project between the Department of Zoology and Entomology, the Department of Medical and Surgical Research, and the Department of Orthopedics. This arrangement makes possible a complete series of studies beginning with the rearing of the flies and ending with the treatment of selected patients in the hospital.

REARING OF FLIES.

Several articles giving methods of maintaining cultures of flies have appeared recently, particularly those of Elizabeth K. Elgin at the Children's Hospital School (Baer, 1930–1931) and that from the Naval Medical School by Murdock and Smart (1931). While the methods employed and described by the above writers show the feasability of cultivation of larvæ for clinical purposes, much is yet to be learned concerning the factors of food, temperature, humidity, light and efficiency in

handling. These problems have been and are now under study at the University and the following information is a preliminary report of our experiences and results during the past year.

Our work has been restricted largely to the two species of blowflies *Lucilia seracata* and *Phormia regina*. These are two of our more common blowflies, easily obtained, easily reared in captivity and are the two that have been most generally used so far in the clinical work of others.

Cages.—The size and shape of culture cages is largely a matter of convenience. We use cages of about one cubic foot capacity because of ease in handling and cleaning. In cages of this size it has been found that a population in excess of 200 to 250 flies gives signs of overcrowding. Gauze or cheese cloth is to be preferred to wire screen as a covering for the cage. The flies in screen cages are more easily disturbed by objects moving near the cage, such excitement resulting in broken wings and a decrease in egg laying. Also gauze is easily replaced when soiled.

Cabinets.—Special cabinets in which the temperature and humidity may be varied permit control of oviposition, which may be desirable as will be brought out later. However, in laboratories or rooms where the temperature does not fall below 18° C. nor rise above 32° C. cabinets are not essential and our results under these conditions have been quite satisfactory. If plenty of fresh drinking water is supplied at all times the relative humidity of the air is not important as long as it does not fall below 35 per cent nor rise above 85 per cent.

Foods.—Murdoch and Smart (1931) and Elgin (Baer, 1930–1931) have discussed their methods and suitable foods in recent publications, and we have also experimented considerably in this field. After testing a variety of natural foods and a number of synthetic ones we have reached the conclusion that, if plenty of drinking water is supplied by inverting a small beaker upon a circle of filter paper in a petri dish, the only other food requirements may be adequately met with dry granulated sugar and fresh lean meat. This makes a decidedly simple diet which can be readily handled and has given very satisfactory results over a period during which a large number of consecutive generations have been reared. Elimination of liquid foods and syrups lessens the mortality from drowning and from poisons due to fermentation. The dry sugar can be

eaten readily by the flies and is kept in the cages at all times except when the flies are ovipositing. Meat should be fed at least once in each two days. It may be fed each day if the eggs laid can be used as frequently as that.

In a series of experiments on foods for larvæ, conducted under conditions of controlled temperature and humidity, the following foods were used: (1) lean beef, (2) lean beef and beef fat, (3) lean beef and trypsin, (4) lean pork, (5) beef liver, (6) fish, (7) boiled egg, (8) dried blood and casein mixed with water. Numbers 1, 2 and 4 gave the most rapid rate of development and seemed best in all other respects although 6 and 8 were utilized almost as readily by the larvæ. The life cycle was completed on all of the foods and there was no noticeable effect on the sex ratio.

Not infrequently larvæ leave their food supply before they have fully developed. Wardle (1930) states that relative humidity of the atmosphere is of considerable importance as a causative factor and that if it falls below 60 per cent the larvæ will leave the meat. We have not found this to be true if the meat does not become too dry. However, there are two factors which do play an important part in producing this reaction: overcrowding of the food supply, and, probably of primary importance, the accumulation of gases in the container used for rearing. Experiments run with a ventilator system for some of the containers and without for others demonstrated this fact.

Pupation Jars.—When larvæ are full grown they leave the food. If just prior to this the culture vessel in which they are feeding is placed in a larger container with strips of crumpled paper toweling, the migrating larvæ will crawl through the paper thus drying and cleaning themselves. They may be left here to pupate, or better, they may be removed and scattered through cheese cloth in another container. The larvæ will work their way into the folds of the cloth and there come to rest. This prevents their collecting in large writhing masses thus disturbing each other continually and probably delaying pupation. The cloth is also decidedly easier to handle than soil or sand, the natural repositories for pupæ. When pupation is complete the cloth is spread out and the pupæ removed and placed in petri dishes until emergence starts, after which they are transferred to the cages.

Segregation of the pupæ and the sex ratio.—Some workers have attached considerable importance to the matter of sex ratio in the culture cages. This is not of sufficient importance to justify the amount of labor required to count out the sexes for each cage. If a large stock of prepupæ are obtained and the first pupæ that form removed, they will, upon emergence, be found to have yielded more males than females. Likewise, the last ones to pupate will yield more females than males. If, however, all are permitted to pupate before being counted out into whatever numbers are desired for cage lots, the lots upon emergence will be found to show a sex ratio of approximately one to one. A preponderance of males is not undesirable as careful counts have shown that the males die in larger numbers during the first two weeks of a cage history.

Temperature and Oviposition.—The entire procedure of fly rearing centers around oviposition since upon this depends the supply of larvæ for the clinic. For this reason, we have paid more critical attention to this than to any other one problem. It has been studied for more than a year and over many generations. For this work we have used mostly *Phormia regina.* While light and humidity exert a minor influence, the controlling factor is unquestionably temperature. These flies have an oviposition range of from 20° C. to about 34° C. with an optimum near 26° C. At the lower temperatures, the longevity of the flies is greatly increased but the number of *eggs per female per day* is greatly decreased. At the higher temperatures, the number of *eggs per female per day* is increased but the total number of *egg-laying days* is decreased because the flies do not live so long. These two factors tend to equalize each other at the extremes but a temperature near 26° C. gives the *greatest total deposition of eggs per female.*

The practical application of these studies is self evident. If the clinical material makes it necessary to speed up the production of eggs it can be accomplished within two days by increasing the temperature in the cages to approximately 30° C. and supplying plenty of food and drinking water. However, it must be remembered that the flies will not live so long at this higher temperature and will have to be replaced at an earlier date. Consequently, the total number of eggs from any one cage will be reduced. This type of behavior in oviposition conforms to that worked out for a number of other insects that have been studied.

STORAGE.

Another problem of practical importance is the possibility of maintaining reserve stocks for quickly increasing the number of adults producing eggs, or for safeguarding against any sudden mortality thus endangering the supply of sterile larvæ for the clinic. Cold storage has been resorted to for this purpose.

The mortality of eggs in storage is too great after seventy-two hours to be of much practical application. Larvæ of various ages show the following results. Newly hatched larvæ cannot be held, to advantage, much more than one week. Larvæ, which have fed for twenty-four to thirty-six hours, will continue to feed, if returned to the food, after two or three weeks in storage. Some have been held for four weeks in refrigeration but the mortality is high. Larvæ that were full grown and ready to migrate from the food were held four weeks after which they pupated and emerged 88 per cent. The temperature used was 8° C. to 10° C. Longer periods of storage ranging from six weeks to six months, over a wide range of temperatures, gave results with a mortality so high that they were of no value. These observations offer obvious possibilities.

The storage of pupæ and adults has been tried with some success. They can both be held for one, two, or three weeks. However, at present, the storage of larvæ seems to offer the greatest possibilities.

PRODUCTION OF STERILE LARVÆ FOR THE CLINIC.

From the point of view of the laboratory, the chief objective is the production of sterile larvæ for the clinic. This part of the work is of such great importance that the utmost precaution must be followed in its pursuit. The eggs are collected from slices of fresh beef that have been placed on circles of filter paper in petri dishes. The dishes and paper have been previously autoclaved to reduce the possibility of contamination. Such preliminary precautions have shown that they contribute materially to success in the sterilization of the eggs. With flamed forceps the eggs are removed from the meat, placed in sterile vials and labeled. Within twenty-four hours they are subjected to a sterilization procedure which does not materially affect the hatching but which does eliminate the ordinary bacterial contaminants when the precautions already outlined are scrupulously adhered to. The technic employed at present

for planting the eggs is essentially that worked out in co-operation with Dr. G. F. White of the United States Bureau of Entomology at Washington, D. C. It consists of dissolving the egg masses apart by shaking not too vigorously in a vial of sterile saline with glass beads. The saline is then pipetted off and replaced by a solution of bichloride of mercury (1:2000) in 25 per cent ethyl alcohol in which the eggs are bathed for not less than fifteen minutes nor more than twenty minutes. They are then poured through a previously sterilized unit consisting of a Gooch crucible containing a small circle of cheese cloth which strains out the eggs. After washing thoroughly with sterile saline to remove any excess of the sterilizing solution the cloth containing the eggs is removed with sterile forceps and placed in a sterile tube of autoclaved agar containing a small amount of meat, much as any bacterial culture might be made. Some of the eggs and the tubes of young larvæ are tested for at least three days for aerobic and anaerobic bacteria before they are released to the hospital for use in clinical cases.

The possibility of retarding or suspending the metabolic processes in the larval stage has been mentioned above as a solution to the problem of maintaining a sufficient reserve of potential flies. This temperature control of larval development has been utilized also in the establishment and maintenance of reserves of larvæ for clinical use. Newly hatched larvæ are too small or too young as a rule to survive immediate implantation in a wound. Therefore, a certain minimum size for wound implantation which is attained in from twenty-four to thirty-six hours at 37° C. or in 72 hours at room temperature (24° C.) is desirable. When the optimum size of the larvæ has been reached, it is possible to suspend growth and development temporarily by reducing the temperature to 8° to 10° C. If the larvæ introduced into a wound are within the seventy-two hour (24° C.) growth size (even though kept for from fourteen to eighteen days at this stage by low temperature) a period of from four to five days of scavanger activity may be anticipated before pupation occurs and a new implantation is required.

CLINICAL RESULTS.

It must be emphasized that the use of fly larvæ in osteomyelitis in no sense eliminates the surgical aspects of the treatment, but is advanced as a method of after treatment

superior to those formerly advocated. The success of any form of treatment in the disease is conditioned very largely by two factors: (1) the age of the patient, and (2) the duration of the disease. Acute or chronic osteomyelitis seems to heal more readily in the very young patients, and the most resistant and difficult cases to treat satisfactorily are those of many years standing in elderly patients. Thus, the importance of an effective treatment early, that the changes which come subsequent to repeated relapses and operations may not jeopardize the possibility or permanent cure.

To Baer's 89 reported cases may be added 17 which have had more or less intensive maggot treatment following operation in the osteomyelitis clinic of the Ohio State University during recent months. In 12 of these cases healing occurred promptly in from four to nine weeks. The remaining 5 represent the first cases in our series and did not have the full benefit of the treatment because of certain limitations then existing in technic and experience. It must be pointed out that success depends in great measure on a certain acquired experience both in the establishment of an efficient laboratory routine and in the effective handling of the treatment in the patient by the surgeon. More complete data on the cases treated in this study are being presented in another communication (Wilson, Doan and Miller, 1932), together with the technic of applying and "caging" the larvæ within the infected areas of bone and tissue destruction.

The mechanism by which larval infestation assists nature in the elimination of infection and the promotion of healing is, of course, one of the chief objectives of this joint study. Through the interest and cooperation of Professor Wm. A. Starin, of the Department of Bacteriology, it has been determined from cultures of larvæ, taken from our stocks for clinical use, that no bacteriophage principal has been present, which, if introduced into the lesions inadvertently with the maggots, might have exerted a lytic effect upon the staphylococci, which have been found almost uniformly to be the causative agent in this series of cases. We have observed a marked change in the hydrogen ion concentration of the wound from an acid to an alkaline reaction following maggot implantation. Does this inhibit pathogenic bacteria? Do the enzymes or excretions of the larvæ exert any direct effect upon the healing process? Or, is it a vital phenomenon wholly related to the

scavenger propensities of this organism for dead tissue? The more or less empiric observations of clinical healing will not suffice indefinitely. An answer to these various questions must be sought for as their satisfactory understanding is essential to the scientific approach to that larger problem of wound healing and tissue repair, toward which the future work of this group is being directed and to which we feel the use of fly maggots in osteomyelitis may contribute.

The osteomyelitis clinic, which is under the direction of the College of Medicine at both the University and Children's Hospitals, is to be continued through the coming year and is available to the sufferers from this malady from anywhere in the state or surrounding community.

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THE ANT, POGONOMYRMEX OCCIDENTALIS, CR., ASSOCIATED WITH PLANT COMMUNITIES.

ARTHUR C. COLE, JR.,
Ohio State University.

Introduction.

In view of the fact that *Pogonomyrmex occidentalis* exhibits a wide range of distribution in the western United States it seems advisable, in this paper, to relate it to two contrasting areas, one, Tooele Valley, Utah, the other, Craters of the Moon National Monument, Idaho. Each area represents a series of distinct vegetational zones.

Tooele Valley, Utah.

Tooele Valley, Utah is bounded by the Stansbury Mountain Range on the west, the Oquirrh Mountains on the east, on the south by a spur of the Stansbury Range and on the north by the southern shore of Great Salt Lake. The area of the valley floor roughly totals 250 square miles.

A wide range is shown in the salinity, or the "alkali" content of the soils of the Tooele Valley. The soils of the foothills are characterized by a low salt content while those of the flats adjacent to the lake are highly saline. These salts comprise sodium chlorid and smaller quantities of the soluble salts of potassium, magnesium and calcium.[1]

The vegetation of the valley is markedly distributed into vegetational zones (Fig. 1) and the survey of the author, relating to the distribution of *P. occidentalis*, was entirely conducted in these various zones, beginning at the shore of the lake and extending to the foothills of the mountains.

The ant in question constructs dome-shaped mounds with surrounding circular areas cleared of vegetation, on level or gently-sloping ground.[2] These mounds are composed of small pebbles or other material and generally vary in composition

[1]Data of Kearney, T. H., et al., from "Indicator Significance of Vegetation in Tooele Valley, Utah." *Jour. Agr. Res.*, Vol. 1, No. 5: 370-372. 1914.

[2]Cole, A. C. "The relation of Pogonomyrmex occidentalis to its habitat." (To be published in Ohio Jour. Sci.)

with the surrounding strata. The ants obtain their food by carrying seeds from nearby plants and storing them in more or less specialized chambers within the mounds.

The Salt Flats.

These flats (Fig. 2) border the lake and are composed of a sandy stratum containing about two percent sodium chlorid. The flats adjoining the lake support no vegetation but as one proceeds toward the mountains distinct plant communities are observed on the salt flats, supporting *Allenrolfea occidentalis*, *Salicornia utahensis* and *Salicornia rubra* as dominant species. In these communities few and scattered mounds of *P. occidentalis* were observed. The mounds were, as a rule, small and distinctly cone-shaped and were situated in open spaces between plants. (Fig. 3).

Such a location is very different from normal upland habitats of the ant in soils of considerably less salinity. The brood is apparently well able to mature under extremely saline conditions. The stored seeds of greasewood and shadscale, carried from nearby areas, were grouped in chambers very near the surfaces of the mounds. By keeping the seeds dry in this manner germination was retarded to a marked degree. The brood chambers, however, were well under the surfaces of the mounds, sometimes at a depth of two feet, where the brood was all but bathed in the salt water from the lake. Such an unusual habitat serves to exemplify the plasticity of the mound-building instincts of the ant.

The Grass-Flat Communities.

In these communities, where *Distichlis spicata*, *Sporobolus airoides* and *Chrysothamnus graveolens glabrata* dominate (Fig. 4), *P. occidentalis* mounds are few and widely scattered. At no time did I observe two mounds closely adjacent to one another. The mounds were always large, distinctly cone-shaped and with somewhat regularly-circular denuded areas usually cleared of all vegetation. In spite of the abundance of nearby seeds of *S. airoides* and *D. spicata* the ants were more inclined to harvest seeds of shadscale, greasewood and Russian thistle. These were found in chambers, often with the brood, at a depth of three to fourteen inches from the apexes of the mounds.

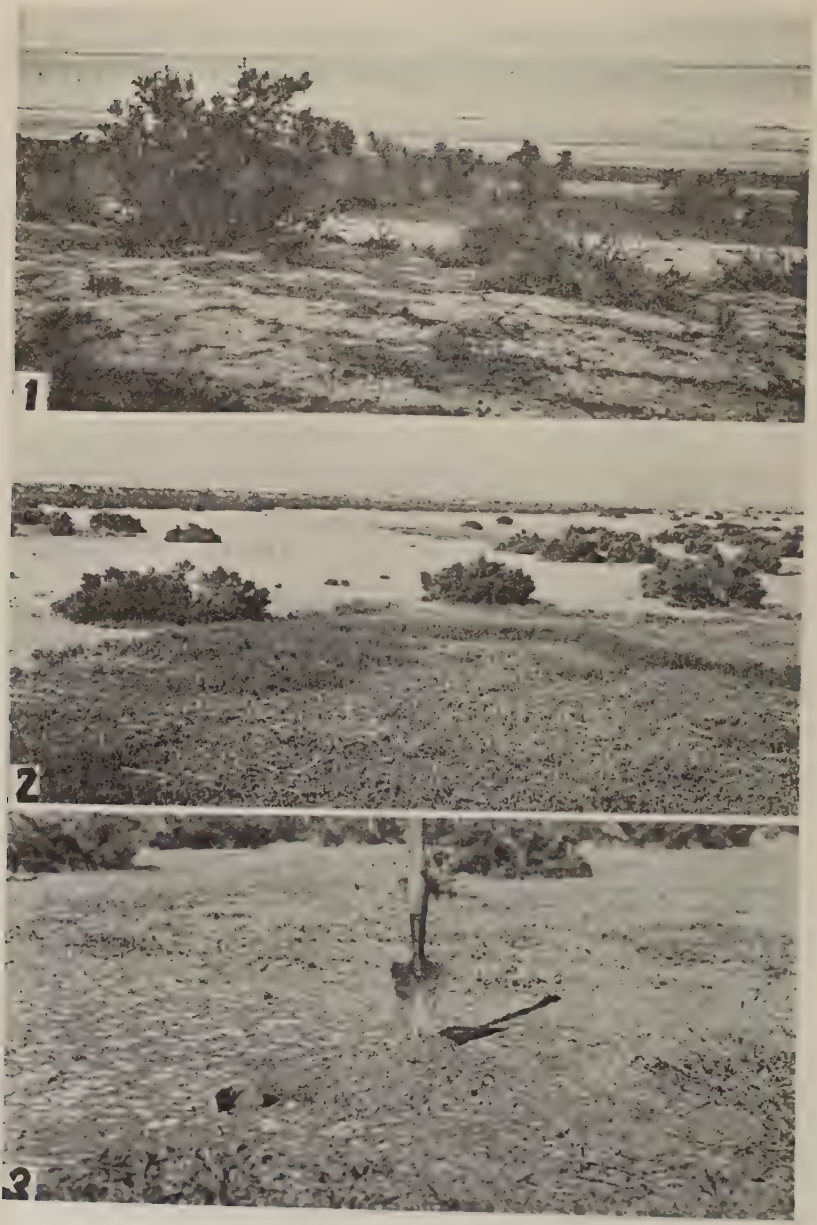

FIG. 1. Salt flats of Great Salt Lake illustrating the zonal arrangement of vegetation. In the background is the Allenrolfea community and in the foreground clumps of greasewood. (Original).

FIG. 2. Salt flats of the Tooele Valley with wide expanses of bare areas in the background. The vegetation in the foreground is salt grass (*Distichlis spicata*) and in the background *Allenrolfea occidentalis*. (Original).

FIG. 3. Mound of *Pogonomyrmex occidentalis* in a community of *Allenrolfea occidentalis*. Tooele Valley, Utah. (Original).

FIG. 4. The grass-flat community of Tooele Valley. Note the scattered plants of rabbitbrush (*Chrysothamnus graveolens glabrata*) associated with tussock grass (*Sporobolus airoides*). (Original).

FIG. 5. Mound of *Pogonomyrmex occidentalis* in the Greasewood-Shadscale Association. Note the large cleared area surrounding the mound. (Original).

FIG. 6. A mixture of vegetation extending out on the salt flats. The darker plants are those of greasewood (*Sarcobatus vermiculatus*). (Original).

The Greasewood-Shadscale Association.[3]

This association is so termed from its dominant members, *Sarcobatus vermiculatus* and *Atriplex confertifolia*. It forms a wide belt across the valley between the grass flats and the schadscale association. Enough soil moisture is available for the survival and growth of greasewood and yet the upper two feet of surface soil are dry enough to support shadscale.

Mounds of *P. occidentalis* are comparatively abundant in this association (Fig. 5) averaging two feet in height and containing large numbers of workers and brood. As the vegetation of this association approaches the salt-flats the schadscale gradually disappears due to the increase in moisture content of the soil. Likewise, as the soil moisture becomes greater *occidentalis* mounds become fewer and, at the juncture described above, the average number of mounds correlates with that of the salt flat communities.

Seeds harvested by the ants consist chiefly of those of schadscale and greasewood together with those of *Bromus tectorum*, an annual typical of this association. They are lodged in chambers, with or without brood, in a position in about the centers of the mounds. The brood chambers are usually found at this level also but may extend below the ground level.

The Schadscale Association.

Dominating is *Atriplex confertifolia* in a minor society of other vegetation including *Poa sandbergii*, *Kochia vestita*, *Opuntia sp.*, *Artemisia spinescens* and *Lepidium jonesii*. *Occidentalis* mounds are only slightly more numerous than in the mixed greasewood-shadscale association and are most commonly found in somewhat open, grassy areas. Seeds harvested by the ants include those of *Poa sandbergii* together with those of greasewood and shadscale. The brood chambers, as well as the seed chambers, are situated near the bases of the mounds or often well under the ground level. The mounds are composed of pebbles and are often covered with a layer of chaff from harvested seeds.

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[3]The term "association" in this paper is used as defined by Kearney, T. H., et al. (*Jour. Agr. Res.*, Vol. 1, No. 5: 374, (1914), as "an assemblage of plants occupying a relatively uniform environment, having an easily recognizable appearance or 'physiognomy' and characterized by the predominance of one or a few species."

Large patches of short Russian thistle are succeeding some of the natural vegetation and in these "islands" many mounds of *P. occidentalis* are aggregated. Under these conditions the Russian thistle provides a great quantity of seeds which are harvested by the ants.

The shadscale of this association often extends out on the salt flats and usually terminates in a wild mixture of vegetation (Fig. 6). Many of these ridges also extend into the lake. In these places mounds of *occidentalis* follow the trend of the dominant and appear abundantly on the ridges.

The Kochia Association.

The Kochia association lies as a narrow, continuous belt extending across the valley between the shadscale area and the lower boundary of the typical sagebrush association. The plants are rather widely separated resulting in a large number of intervening bare areas from which most of the former grasses have been removed by pasturing. In such open areas mounds of *occidentalis* are occasionally to be found, their numbers, however, being far less than those of the preceding communities except perhaps the salt flats. Mounds of *occidentalis*, when they occur, are small, irregular and wind-blown, composed of earth instead of pebbles and consisting of only a comparatively few occupants. The brood chambers are proportionately small and irregularly situated throughout the mounds. The seed chambers are larger than the brood chambers and are often stocked with an abundance of shadscale, greasewood and Russian thistle seeds.

The Sand-Hill Mixed Association.

The sand-hill mixed association[4] is in the southern part of the valley. There a wide variety of vegetation, of which *Juniperus utahensis* and *Artemisia tridentata* are representative, grows on sand dunes or sandy ridges formed by the continuous sweep of the southwest winds. The stratum is almost pure sand some of which is in continuous motion. In such regions we should not expect to find *P. occidentalis* mounds in any great numbers. Only one mound was located and that partially protected from the wind by surrounding plants of sagebrush. This mound was in an incipient state and it is doubtful whether it would have ever become a more or less stable unit.

[4]Terminology of Kearney, et. al., ibid.

The Sagebrush Association.

The sagebrush association is one of the most important vegetational units of Tooele Valley. It is found on the gently-sloping foothills and bench lands of the mountains, the alluvial fans and the sand hills. The dominant of this association is *Artemisia tridentata* which is associated with a number of other perennials as well as numerous annuals and biennials, among the most important being *Bromus tectorum* and *Erodium cicutarium.*

In this association *occidentalis* mounds reach their quantitative peak. In no other community do we find as many mounds so closely aggregated with one another and continually increasing in quantity. In fact, it is safe to estimate that there are approximately as many incipient colonies of the ant as there are fully developed mounds. The mature mounds are large, averaging two feet in height, and are surrounded by large cleared areas.

In pepper-grass (*Lepidium sp.*) "openings," scattered throughout the sagebrush association, the mounds were more closely aggregated than in any of the other areas of the association. In fact it is barely possible that the Lepidium in this locality started from the germination of seeds harvested by *occidentalis* workers from outlying areas, for, in many cases, the mounds as well as the denuded areas supported scattered individuals of the plant. Mounds of *occidentalis* opened in this area were found to contain large quantities of Lepidium seeds, often surpassing the number of Bromus seeds, though *Bromus tectorum* was extremely abundant throughout this association.

The Sagebrush-Juniper Community.

The sagebrush-juniper community is a variation of the typical sagebrush association and is located on the lower mountain slopes. It also extends into the upper portion of Tooele Valley. In this community there is a marked deficiency in the number of mounds of *P. occidentalis* in spite of the more pebbly soil, common to areas of *occidentalis* abundance. Scattered mounds were found in the more open areas between the junipers. These contained large quantities of *Bromus tectorum* seed, commonly present in the community.

Craters of the Moon National Monument, Idaho.

The Area in General.

Craters of the Moon National Monument lies 26 miles southwest of Arco, Idaho. The soil of the region is largely composed of cinders formed of basalt lava from both aa and pahoehoe lava flows.[1] The pahoehoe type covers about half of the area of the Monument. It affords a smooth, billowy appearance very distinct from the rough, jagged aa flow which occupies the remainder of the area. Many hills of cinders which originated from adjacent cinder cones dominate the landscape. On these hills most of the vegetation is found.

If Irving[2] refers, as Stearnes[3] believes, to the Monument as "an area of about 60 miles in diameter, where nothing meets the eye but a desolate and awful waste, where no grass grows, nor water runs, and where nothing is to be seen but lava," he made far from accurate observations of the area. The vegetation is surprisingly abundant and is separated into various and distinct plant communities. These communities are arranged as various zones in the Monument, their positions apparently determined by soil texture, moisture and hydrogen-ion concentration.

The Semi-desert Communities.

1. The Sagebrush Community:

The sagebrush community is one of the most prominent vegetational units of the region. It occupies, in pure stands, many areas within the Monument but as a rule it is found on the cinder buttes. In association with the dominant sagebrush are *Agropyron repens*, *Agropyron smithii*, *Purshiana tridentata* (buck bush), *Chrysothamnus graveolens* (rabbit brush) and *Bromus tectorum* (brome grass).

In the sagebrush community mounds of *Pogonomyrmex occidentalis* are found in greater abundance than at any other point in the limits of the Monument. The majority of them are of average size, about two feet in height and three and

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[1]Stearns, H. T., *A Guide to the Craters of the Moon National Monument, Idaho.* Bull. Idaho Bur. Mines & Geology, XIII (1928), 7–59.

[2]Irving, Washington, *The Adventures of Captain Bonneville.* U. S. A., Hudson ed., New York, 1868, 203.

[3]Stearns, op. cit., p. 7.

one-half feet in diameter, and are surrounded by large areas from which the vegetation has been cleared by the ants. Most of the mounds are composed of cinders which offer fair insulation of the brood in chambers at the bases of the structures.

2. The Sub-alpine Meadows:

On the tops and upper slopes of the higher hills are quite dense meadows of the following vegetation:[4]

GRASSES

Ericoma hymenoides (Indian millet).
Oryzopsis bloomeri (wild rice).
Sitanion cinereum.
Stipa occidentalis.
Melica bella (rye grass).
Sitanion rigidum.
Stipa comata (spear grass).

SHRUBS AND HERBS.

Agoseris sp. (goat chicory).
Castelleja pinetorum (paint brush).
Crypthantha torreyana (borage).
Eriognum depressum.
Eriognum subalpinum.
Eupatorium occidentale (boneset).
Crepis acuminata.
Gayophytum ramosissimum.
Lewisia redeviva (bitter root).
Lygodesmia spinosa (prairie pink).
Opuntia xanthostemma (cactus).
Pentstemon deustus.
Potentilla biennis (cinquefoil).
Salsola pestifer (Russian thistle).
Amelanchier alnifolia (service berry).
Circium orthe (Canadian thistle).
Eriognum aridum.
Eriognum ovalifolium.
Eriognum vimineum.
Galium boreale (bedstraw).
Coleosanthus grandiflorus.
Heuchera ovalifolis (alum root).
Lupinus tenulus (lupine).
Opuntia polycantha (cactus).
Oreocarya dolosa (borage).
Philoria tenufolia (desert pink).
Potentilla dichrona.
Ribes cereum (currant).

In spite of the abundance and the wide variety of vegetation *occidentalis* mounds are very scarce, only an occasional colony being found. In mounds which were opened the seed chambers were in about the centers of the mounds and were stocked with seeds of many of the plants listed above.

The Laval Plant Communities.[5]

1. The Cinder Meadows:

The cinder meadows[6] are usually located on the slopes of the cinder buttes and rarely on the sides of the spatter-cones.[7] The representative vegetation is not abundant but *Lewisia redeviva, Mimulus nanus, Eriognum depressum, Eriognum aridum,* and *Eriognum ovalifolium* are outstanding plants.

[4]Ibid.
[5]Terminology of the author.
[6]Ibid.
[7]Stearns, op. cit., p. 23.

The few and scattered mounds of *P. occidentalis* in the cinder meadow community are small and irregularly constructed, with few workers and little brood. The seeds stored in the somewhat specialized seed chambers represent those of *Salsola pestifer*, *Stipa comata*, and *Stipa occidentalis* and not those of plants dominating the meadows. From the appearance of the mounds and the environmental conditions under which they survive the somewhat recent invasion of the ant is evident.

2. The Pine Community:

The pine community is probably the least important and most poorly represented community of the Mounment. The dominant, *Pinus flexilus*, (limber pine), never exists in pure stands at the Craters of the Moon. Unfavorable environmental factors have dwarfed and twisted the trees and have limited their numbers and spread. The limber pine is better adapted to growing on the cinders than on the lava[8] and it is there that it is found in its greatest numbers. Associated with *Pinus flexilus* are *Prunus melanocarpa* (choke cherry), and *Amelanchier alnifolia* (service berry) as well as *Artemisia tridentata* (sagebrush) and *Chrysothamnus graveolens* (rabbit brush).

Pogonomyrmex occidentalis is represented in the community by a few mounds usually scattered in the interspaces of the sagebrush plants but occasionally at the bases of the pines. The mounds are small, irregular in outline and composed of coarse cinders. The brood chambers are small, few in number and dispersed throughout the mounds. The chief seeds harvested by the ants are those of *Amelanchier alnifolia* and *Salsola pestifer*.

The Alpine Groves.

Small stands of quaking aspen, *Populus tremuloides*, grow on the slopes of Big Cinder and Fissure Buttes, two prominent cinder cones of the region, where the snow lies late in the spring. Only a few plants are associated with *Populus tremuloides* in the community, among the more outstanding being *Stipa comata* and *Agropyron spp.*

Of the limited number of mounds of *P. occidentalis* present in the community all are in the large bare areas between the vegetation. They are generally small and somewhat incon-

[8]Ibid., p. 50.

spicuous, without definite cone-shaped outlines and with only slight denuded areas. The brood chambers and the seed chambers are few in number and are irregularly located throughout the mounds, many of them even below the ground level.

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FOOD OF THE MUSKRAT IN SUMMER.

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Few attempts have been made to study the food supply of the muskrat under natural conditions in the northern states. Almost every paper on the animal lists some foods, but most dismiss this subject with the statement that they eat cat-tails and other marsh vegetation. By far the best list of foods published (Johnson, 1925) names several foods of animal origin and some twenty-six plants. In addition to this descriptions of what portion of the plants is consumed and, in some cases, how it is eaten, are given. Arthur, (1928, p. 338), lists the foods usually eaten in Louisiana, as does Svihla (1931).

The work upon which the following report is based was carried on from June 8 to September 14, 1930, while the writer was employed as temporary Mammalogist, Division of Conservation of Ohio. The work was part of a survey of the muskrat in the state, and was carried on under the direction of E. L. Wickliff, Chief, Bureau of Scientific Research. The indebtedness to Mr. Wickliff for the opportunity to do the work, and for his suggestions and co-operation is gratefully acknowledged by the writer. Professor L. H. Tiffany is responsible for many of the identifications. Without his help the list of food plants would be shorter and would lose much of its value. Any mistakes are the writer's, who willingly admits that his knowledge of botany leaves much to be desired.

The habitats of the muskrat in Ohio may be divided roughly into two types: marsh or swamp habitats and stream habitats. There is no accurate method available which would permit an estimate of the relative number of animals in each habitat, but it is the opinion of the writer that the numbers in Ohio are approximately equal. The concentration in marshes is more noticeable, but the larger area of stream banks, as compared with marshes equalizes the numbers.

In the marshes, which are located chiefly along the western shore of Lake Erie, but occur locally over much of the northern half of the state, the study of food plants is complicated by the

house building activities of the muskrat. It is often a problem to determine just what has been cut for food, and after eating, how much was used in the construction of houses, and what was gathered for such building. As the activity of house building is seasonal, the problem is somewhat simplified. Plants are listed as food only where the animals were observed feeding upon them, or where the plant has been cut and portions eaten before being utilized for raft or house building.

Where dikes, ditch sides, or roadways pass through a marsh the muskrats feed on some of the plants found in such places, in addition to the marsh plants which furnish the bulk of the food. The plants eaten here offer a transition from the marsh plants to those eaten by the stream or "bank rats."

As would be expected, the largest variety of foods is eaten by these "bank rats," for they range well back from their burrows in search of desirable foods. When food plants are found they may be cut and dragged entire to the water, they may be cut up into convenient size for transportation, or they may be consumed on the spot. Sometimes one finds all three conditions on the same plot. Since these animals live in burrows and do not usually use plants except for food and bedding material, the problem is simpler than in the marsh; but care must be exercised in determining just which plants were used for food. In most burrows the usual bedding was grass or sedge. In the houses cat-tail appeared to be used to the exclusion of other materials.

During the course of the survey attempts were made to visit certain places at frequent intervals to study the seasonal variation in foods. The habit of the muskrat is to take most of its food to some protected place for consumption. These feeding stations are usually located in a burrow mouth, under projecting roots, or under a snag or tree at the edge of the water. In seasons of low water these piles accumulate until they may amount to two or three bushels, for only a small portion of each plant may be eaten. High waters remove these piles, so it is relatively easy to determine the length of time that has elapsed since the pile was started. Thus a good idea of the seasonal variation may be formed from a study of these accumulations.

With the "marsh rats" the formation of rafts by the accumulation of debris from feeding offers some information as to seasonal habits; but since the raft is usually in still water, the accumulation is not so easily dated. The writer proposes to

destroy some rafts in an attempt to study seasonal feeding habits in such areas.

Little or no work on the winter foods has been done. It is to be hoped that this work will be carried on, for the critical period, so far as food supply is concerned, is in winter and early spring.

One interesting sidelight brought out is the fondness of the muskrat for certain plants not native to America, but invaders from Europe and Asia. The muskrat, except for a few that have been introduced into Europe, is confined to North America. A recent study in Saxony (Ulbrich, 1927) lists *Acorus*, *Elodea*, *Potomogeton*, *Alisma*, and species of *Gramineae*, *Cyperaceae*, *Juncaceae*, *Nymphaeaceae*. Representatives of these groups of plants are eaten in Ohio. At least one, *Elodea*, may have been an American species introduced into Europe. This brings to mind the fondness of a native American cat, the mountain lion, for catnip (*Nepeta Cataria*) which was introduced from Europe where the mountain lion does not occur. How long were the plant and mammal lines separated before they were reunited? The same question might be asked in connection with the muskrat.

The foods listed here are by no means exhaustive, and are offered only as a beginning.

ANNOTATED LIST OF FOOD PLANTS.

Common cat-tail (*Typha latifolia*).
Narrow-leaf cat-tail (*Typha angustifolia*).

The common cat-tail is the outstanding food of the marshes. It is not, however, the sole food anywhere, as the writer will show. Because of its conspicuousness in growing, the amount cut, and its use both as bedding and building material in houses, the common impression has grown up that it furnishes everything that the muskrat needs. It forms the back bone of the diet, but may be neglected for many other plants, such as the cow lily, Jerusalem artichoke, duckweed, and others.

In eating the cat-tail the rats reach up as far as possible, standing on the hind legs, cut the leaf, and then cut or tear it into pieces several inches in length. After a few nibbles the piece is discarded and another taken up. The food is not washed; the sound of the tearing is audible at a distance of twenty feet. In addition to the leaf the base is eaten as well as the tender shoots from the roots. The roots themselves are not often attacked during this season.

The narrow-leaf cat-tail is not nearly so abundant as the common cat-tail, but is treated in the same way. When drought comes the common cat-tail is better able to resist wilting.

Bur-reed (*Sparganium eurycarpum*).

The base of the stems of this plant are eaten extensively. The cutting is done at the base, after which a small portion is consumed. On several occasions the prickly seed heads had been gnawed, but had not been eaten.

Pondweed (*Potamogeton foliosus*).

A few stems of this plant showed signs of gnawing. While it is used as house building material, it is of great importance neither in this connection nor as food.

Broad-leaved Arrow-head (*Sagittaria latifolia*).

During the early summer the base of the stalk is eaten. Unlike the condition found in New York (Johnson, 1925, p. 249) this plant furnishes considerable food to the muskrats along Lake Erie and in the "bottoms" along Killbuck Creek, to mention but two outstanding habitats. Later on the fruiting heads also were eaten.

Grasses: (*Panicum species*), (*Calamagrostis canadensis*), (*Poa compressa*), (*Poa pratensis*), (*Hordeum jubatum*).

The grasses are treated together as it was impossible for the writer to distinguish between them in the field. The fragmentary condition of many specimens increased the difficulty, so only those species are listed that have been identified by Doctor Tiffany from specimens submitted to him. Undoubtedly many more species are eaten when other food is too tough or too difficult to secure.

Generally only the tender basal stem is eaten as in the sedges and many other plants, but occasional patches of grass are found which show the effects of cropping. Here the grass is kept short by the animals' eating off the top growth without, apparently, any of the material being carried away. Woodchucks, too, attack grass after this fashion. The only other plant so eaten is white clover (*Trifolium repens*) and sweet clover.

On the banks of one pond grass stems had been piled over the entrance to a burrow which had been uncovered by the lowering of the water. These stems formed a half-house, as it were, the bank forming the back half as though a muskrat house had been cut in two and one half placed against the bank. The pond was enclosed in a rat-proof fence and only grass and *Lemna* were available, which probably explains the use of grass stems in construction. The pile contained two bushels or more, all well packed. The restricted diet did not effect the animals adversely, for many were seen, all of which were in good condition.

Under certain conditions grasses may form an important item in the diet of muskrats, and they appear to thrive on it. Of the grasses cut *C. canadensis* is most frequently encountered.

Sedge (*Cyperus strigosus*), (*Scirpus fluviatilis*), (*Scirpus validus*), (*Scirpus species*), (*Carex lupulina*), (*Carex vulpinoidea*).

These families are grouped together, as they were not identified in the field and because they furnished the same type of food. Many

species not listed are consumed, too. As a rule only the tender basal portion of the stem is eaten, although a few fruiting heads were found which showed that the muskrats had sampled them.

Duckweed (*Lemna*).

Muskrats were observed feeding on what appeared to be duckweed. In each case the animal swam about slowly, eating the floating plants with evident relish. The sound was audible at a distance of fifty feet and was very noticeable when the animals were closer. *Lemna* was found also on the tops of houses and at feeding stations. It may have been carried there as building material rather than as food, as it showed the characteristic balled condition of material used in house construction. The abundance of duckweed in certain habitats, notably about the shores of still lakes and ponds, makes it an item of considerable importance, for in most cases where animals were observed eating it, it was chosen in preference to *Typha*.

(*Wolffia*).

What has been said of *Lemna* applies possibly to *Wolffia*. (Johnson, 1925, pp. 248.)

Willow (*Salix spp.*).

Both leaves and bark of the willow are eaten, young shoots, recently cut, being found from time to time. One captive muskrat always ate willow in preference to *Typha*. The abundance of young willows along streams running through pastures does much to encourage the establishment of burrows in this type of habitat.

Elm (*Ulmus sp.*).

The leaves and bark of young shoots of the elm are a favorite food of the muskrat whenever they are available. Sprouts are cut about twelve to sixteen inches above the ground and transported to the water where the leaves and some of the bark are eaten. Cutting apparently takes place as soon as the sprouts leaf out. Elm was eaten in one habitat which was unusually rich in the variety of foods available and where there was no need for eating anything unpalatable. Such efforts were made to secure the elm that the writer is convinced of its desirability as a food for muskrats.

Curly Dock (*Rumex crispus*).

The internodes of curly dock forms an important item of food. In addition to the internodes the leaf base is also eaten at times. Along the Mohican River and most similar streams examined this dock was extensively eaten. Cutting begins early, as the plants are eaten usually before they flower. Later, when the seed has set, the plant appears again at the feeding stations and on the feeding platforms. While no animals were seen eating the matured seed, the frequency of occurrence of empty fruiting calyces indicated that it is the seed for which the plant is cut. That this is an important plant in the diet of "bank rats" is shown by the numbers of plants cut, the distance the animals will travel to secure it, and the large number of localities in which dock

grows. Where both curly dock and cat-tails are available the dock appears to be the favorite. Only the artichoke (*H. tuberosus*) was eaten in preference to dock along many streams.

Bitter dock (*Rumex obtusifolius*).

Where this rather tough plant is available the base of the stems is eaten. As the plant grows on the dikes in the marshes it is fed upon by "marsh rats" as well as "bank rats." It is not an important food plant, as only a few of the more tender leaf stems are cut from each plant. As with *R. crispus*, it is possible that the mature seeds are eaten also.

Smart weed (*Polygonum acre*).

Muskrats cut large amounts of this weed in certain habitats. Very little of each plant is eaten, only a few of the internodes being consumed before the plant is discarded. However, where a small stream passed through an old pasture, large quantities were cut and transported to the feeding places. Such activities indicated that smart weed was forming an appreciable portion of the diet here.

Yellow pond lily, cow lily (*Nymphaea advena*).

In the bottoms, along ditches, and in certain marshy localities the yellow pond lily furnished considerable food. The base of the stems, the basal portions of the leaves and the fruiting body are eaten. Even the root is attacked where the food variety is not great. Possibly the root is of great importance in winter, but it is not much used in summer, except where pressure of numbers has reduced the available food supply. Wherever other plants such as *Typha*, *Nelumbo*, and certain of the sedges are to be had, the cow lily is not eaten to any extent. From these facts one is led to the belief that while it may form the staple diet where other plants are not available, the muskrat is not partial to it.

White lily (*Castalia sp.*).

The basal portion of the flower is eaten to some extent, though not many flowers are attacked. Hence, the muskrats do not destroy many blossoms, nor is the plant of any importance in their economy during the summer.

Water chinquapin, "lotus" (*Nelumbo lutea*).

At Buckeye Lake this plant proved to be the finest type of food plant for muskrats. In the early summer the stem furnishes food, while the leaves are used as a building material. The leaf stem is cut from one to two feet under water, and again an inch from the leaf. Only the central portion of the stem is eaten, the tough outer layer being removed and discarded. In removing this unedible material the stem is not stripped, but is uncovered by biting and pulling off small pieces an inch or an inch and a half long. These pieces were found frequently on the leaves of the *Nelumbo* where the rat had rested while making a meal. Later in the summer the "nuts" or seeds in the fruiting head are eaten. Oddly enough, few, if any, of the fruiting

stems had been cut before the seed ripened. As the root is farinaceous, it, too, may serve as food when green stuffs are not available.

Such an admirable food plant deserves attention from the ranchers of muskrats and state game commissions, for it will grow in water too deep for *Typha*, and is well liked. It should be planted extensively in waters where an additional source of food is wanted.

Water Cress (*Radicula nasturtium-aquaticum*).

A few stems of this spicy plant are eaten. There is very little wasted.

Sycamore (*Platanus occidentalis*).

In August some twigs and leaves of sycamore were found at feeding places, indicating that this tree furnishes food from time to time, but is not a constant source of supply like the willow or elm. This might have been due to the difficulty of securing the twigs rather than to any preference on the part of the animals.

Red clover (*Trifolium pratense*).

There is little waste when red clover is eaten, for a large portion of each plant is consumed. The flowering head is discarded, and it is from this that an idea of the amount utilized is formed. The extensiveness of the cuttings checked well with the number of heads, indicating that only the head was not consumed.

White clover (*Trifolium repens*).

This appears to be one of the favorites, if not the favorite plant, whenever it is available. In one old unused pasture well defined trails led from the stream to patches of clover. These trails ran back to the patches, spread out, and disappeared. These patches had been grazed down well below the level of the surrounding vegetation, and were kept down all through the summer. That this was not the work of woodchucks was evident from the small size of the paths, as well as their direction. Moreover, the woodchucks had been shot and trapped constantly over this area, so were rare or absent. Most of the clover was eaten on the spot, although some was carried to the stream.

This is an important food and one of the best of muskrat foods, as it is a favorite; and, since stems and leaves are eaten, there is little waste.

Sweet clover (*Melilotus alba*).

On the other hand, there is much waste where sweet clover is eaten, for the animals eat a small portion of the stem only. As the clover grows tough with the advance of the season, less and less is cut or eaten. Although abundant in some habitats, sweet clover is not a very important food plant; but when other food plants are scarce, as in an inclosure, muskrats have been known to eat the mature plant, roots and all.

Maple (*Acer sp.*).

Leaves and twigs of maple were found in feeding places along the Mohican during June, but no cuttings were seen. The leaves and some of the bark of the twigs are eaten.

Jewelweed (*Impatiens biflora*).

This is not an important source of food, although it appears from time to time on the piles of discarded foodstuffs. It is abundant along many streams and is easily available. Thus, much would be found at feeding places were it a favorite food.

Water hemlock (*Cicuta maculata*).

This plant may be poisonous to stock, but it is eaten by the muskrat. The stems are eaten, but the leaves discarded, so it is just possible that the stems lack some substance found in the leaves. The name, Musquash root, may indicate the recognition of the plant as a food supply of the muskrat. Not much is found on the feeding places, but neither is the plant itself abundant in any of the localities studied.

Spearmint (*Mentha spicata*).
Peppermint (*Mentha piperita*).

A few stems of each of these plants were found on several rafts. Only a few stems had been cut and only a small portion of each stem eaten.

Common plantain (*Plantago major*)

In early summer the base of the leaf stem and the tips of the leaves are eaten in considerable quantities. Later in the season the same parts of tender plants are consumed, as well as the fruiting heads of more mature ones.

Ironweed (*Vernonia sp.*).

The stems of ironweed are eaten. On July 22 the largest cuttings were found, which marked the period when most was consumed. Although some had been eaten before this date and some was eaten after it, this marked the period when ironweed was most abundant on the feeding rafts and in the accumulations in the water.

Boneset (*Eupatorium perfoliatum*).

Immature plants are eaten during July and August. Only the internodes are eaten, the leaves being discarded. While not a food of importance, considerable quantities are cut and taken to the water.

Golden-rod (*Solidago spp.*).

A small portion of stem about four inches above the ground is eaten. Very few plants are cut at any time, and none after blooming.

Aster (*Aster multiflorus*), (*Aster, spp.*).

Muskrats will travel as much as two hundred and fifty feet from the water to secure aster. Usually only the tops are cut off, which induces branching. In one plot this cutting of the tops had been done several times until the plants had taken on a bushy appearance; for not only had the tops been eaten, but the ends of the lateral branches had been eaten also. Even where abundant food is available, aster is eaten extensively.

Giant ragweed (*Ambrosia trifida*).

In June the base of the stem is eaten. Judging from the amount consumed ragweed is relished at this time of the year.

Roman wormwood (*Ambrosia artemisiifolia*)

A few plants of this species were utilized, the tender unfolding leaves at the top having been eaten.

Jerusalem artichoke (*Helianthus tuberosus*).

This very common plant was extensively eaten by the muskrats living along certain streams. On the Walhonding during the middle of June the stems of the artichoke were furnishing more food than all the other sources combined, sedges were second, and *R. crispus* was third. Great quantities of the artichoke had been cut, the leaves and nodes discarded, and the internodes of the plant eaten. Not only was more of this plant cut than all others, but more of each stem was utilized. The preference for this food was such that the animals passed other food plants close to the water to go over the bank to reach it. Many cuttings were found fifty feet from the water. This was not an unusual distance. After cutting off the stem about nine inches above the ground the plant was dragged to the feeding places. As this plant was growing luxuriantly on the tops of unshaded banks and along the edges of cultivated fields, its importance was evident. From the first of June until September the stems of this plant formed a very important item in the diet of muskrats wherever it was available. It is possible that the roots are eaten later in the season.

Yarrow (*Achillea millefolium*).

Although this plant was found at several feeding stations, only a little of the stem was eaten. It was cut before flowering.

White Lettuce (*Prenanthes alba*).

The internodes of a few plants had been eaten to judge from the remains at the feeding places. This plant, too, was cut before mature.

Corn.

Corn planted near marshes or stream banks is attacked. Before the stalk grows tough the basal portion is eaten. After the grain develops the stock is cut and the grain eaten off the ear where it lies. The cob may be carried to the water or den for consumption.

Wheat.

The amount of damage done by muskrats to ripening wheat is not nearly so great as that done by the woodchuck. The muskrat cuts the stalks and removes the unripe grains. Usually the cut stalks are carried to the water before being eaten.

Oats.

Some oat stalks were found along a stream which ran between a field of oats and a field of wheat. Wheat was preferred, evidently, since very little oats had been cut.

Mussels.

While many mussel shells were seen bearing marks and heaps of shells were seen near feeding places, the species of mussels are not listed, since the evidence was purely circumstantial.

Muskrats.

Muskrats killed on unfrequented roadways by passing cars were found to have been eaten by their fellows. This statement is based upon the collection of feces about such carcasses. Just why the animals should pass over an exposed roadway instead of going under a bridge is difficult to understand. Nevertheless, many banks showed well defined trails leading over the bank to cross the road. On one occasion three animals were seen to use such a trail within the hour, while not one animal was detected passing under the bridge during that period.

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POECILICHTHYS OSBURNI, A NEW DARTER FROM THE UPPER KANAWHA RIVER SYSTEM IN VIRGINIA AND WEST VIRGINIA.

CARL L. HUBBS AND MILTON B. TRAUTMAN.

The handsome percid named and described in this paper is the fifth species of fish to be indicated as characteristic of the upper Kanawha system. The others, all cyprinids, are *Notropis scabriceps* (Cope), *N. kanawha* Jordan and Jenkins, *Phenacobius teretulus* Cope and the recently described *Parexoglossum lauræ* Hubbs (1931). All of these species occur, so far as known, solely in the Kanawha River basin above the Kanawha Falls, the position of which is indicated by the arrow in Fig. 1. This upper Kanawha River system, the outlines of which are indicated by the black line in Fig. 1, is in other ways set apart, from the standpoint of fish distribution, as one of the most distinctive subdivisions of the vast Mississippi system.

The Upper Kanawha system is a cut-off portion of the Ohio River system, which is the chief home of *Poecilichthys variatus* (Kirtland), the only species with which *P. osburni* is closely related. The range of *P. variatus* is also indicated, by record stations and by assumed limits, in Fig. 1. The basis for mapping the distribution of *P. variatus* may now be indicated by states:

DATA ON THE DISTRIBUTION OF *POECILICHTHYS VARIATUS*.

All records refer to the Ohio River system, except for the single record stations each in Arkansas and Missouri.

New York.—Recently collected by Dr. John R. Greeley in French Creek, in Chautauqua County, near the western boundary of the state.

Pennsylvania.—Recorded by Bollman (1886: 339); McConnell (1905: 178); Fowler (1919: 70), and Fowler and Carlson (1927: 72). We have no reason to doubt the validity of any of these reports, although only the specimens recorded by Jordan have been seen. One new record for the state, for French Creek, near the New York state line, is indicated on the map. Specimens were recently taken there by Dr. Greeley.

Ohio.—This species was originally recorded from the Mahoning River by Kirtland (1838: 168 and 192), who added, "I am indebted to Mr. Charles Pease for a specimen of the same species taken in the Cuyahoga," which is a small river entering Lake Erie at Cleveland. Unfortunately this record is probably incapable of verification because the stream is now badly polluted. The doubt as to the validity of this record is increased to an almost certain indication of error when we recall that Kirtland mentioned only the Mahoning

River in describing the species (1840: 274, Pl. 2, Fig. 2); that he did not recognize the species now known as *P. coeruleus* until 1854 (p. 4); that he in 1850 (p. 1) recorded *variatus* not only from the Mahoning and Scioto rivers, but also from Chicago, Illinois, and that he, according to Jordan (1885: 163) later regarded Storer's *Etheostoma coerulea* as identical with his own *variatus*. These circumstances warrant us in questionably referring Kirtland's two records of *variatus* from the Great Lakes drainage to *Poecilichthys coeruleus*, which is there the most abundant of bright-colored darters. A few other Ohio records of *P. variatus* are given by Henshall (1888: 80), Osburn and Williamson (1898: 20) and Osburn (1901: 97), but the majority of the records indicated in Fig. 1 were made recently by the Lake and Stream Survey of the

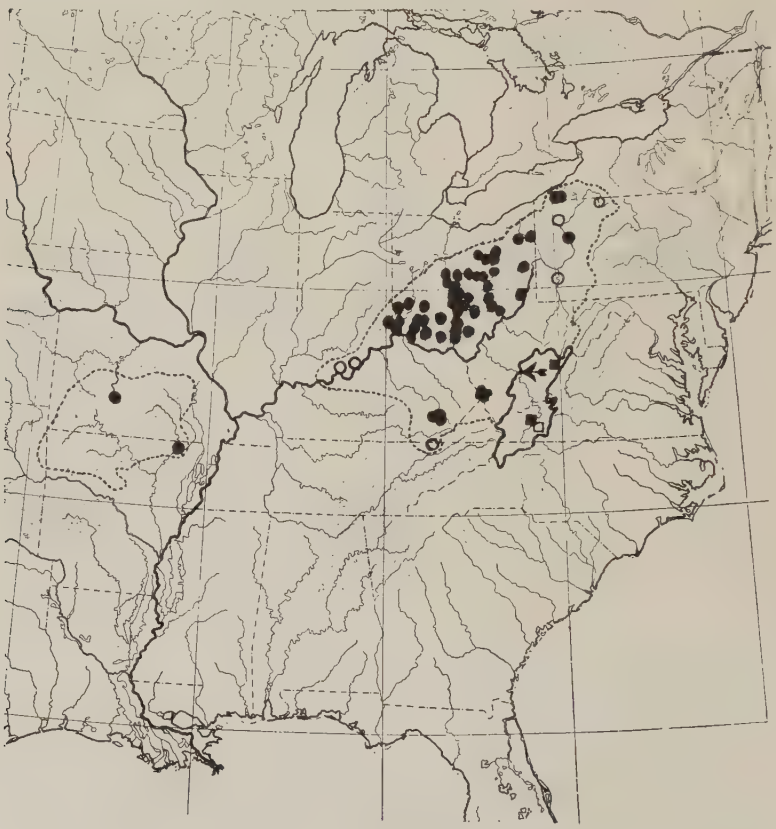

FIG. 1. The distribution of *Poecilichthys osburni* and *P. variatus*.

The supposed range of *P. osburni*, surrounded by a solid line, is the drainage basin of the upper Kanawha system, above the Kanawha Falls, which are located by the arrow.

The range of *P. variatus* as now provisionally determined is surrounded by broken lines.

The solid squares locate the two record stations of typical *P. osburni*.

The hollow square locates the locality where the variant type of *P. osburni* was found.

The solid circles indicate the confirmed record stations for *P. variatus*.

The hollow circles represent the unconfirmed record stations for *P. variatus*.

Ohio Division of Conservation. Other reports of *variatus* for Ohio, as Jordan's (1882: 973), refer either to *Poecilichthys coeruleus* or to *Hadropterus maculatus* (see Jordan, 1885: 163).

INDIANA.—Reported by Jordan (1885: 163; Evermann (1886: 8); Evermann and Bollman (1886: 339); Woolman (1892: 280); Hay (1894: 278), and Cockerell (1913: 156). Some doubt pertains to the last record, which may have been based on specimens holding over on erroneous identification.

WEST VIRGINIA.—Neither Goldsborough and Clark (1908) nor other authors have recorded *Poecilichthys variatus* from West Virginia. The junior author, however, has seen specimens recently taken by John Addair in the Guyandot River at Justice City, Mingo County; in the Tug Fork at Gates in the same county, and at Mohawk in McDowell County, and in Pigeon Creek, an eastern branch of the Tug, at Delborton, Mingo County. We are obliged to Mr. Addair for permission to announce his discovery of this darter in West Virginia. In West Virginia, *P. variatus* is apparently generally distributed except in the territory of *P. osburni*—the Kanawha basin above the falls.

KENTUCKY.—Recorded by Woolman (1892: 280), and Evermann (1918: 358). Some of Woolman's specimens have been re-examined. Evermann's record for the South Fork of the Cumberland was of course based on *P. coeruleus*, which in 1878 passed under the name of *variatus*.

TENNESSEE.—Evermann and Hildebrand's (1916: 450) record, the only one for the state and for the distinctive and rather well-worked fauna of the Upper Cumberland system, though indicated as a hollow circle on our map, is not accepted without reservation. The record was accompanied by no description and was based on only one specimen, which we have not been able to relocate.

ARKANSAS.—The only published records of *P. variatus* for any locality outside of the Ohio basin are (1) the doubted one for Easton, in the Delaware system of Pennsylvania (Jordan and Evermann, 1896: 1070), which record is indicated as surely erroneous by the finding of other western species in the Museum of Comparative Zoology similarly mislabelled "Easton, Pa." and (2) the record for the Arkansas River drainage of Arkansas by Hubbs and Ortenburger (1929: 48).

MISSOURI.—This Arkansas record station is rendered less isolated by the recent finding of this species in the Missouri River system of Missouri, by J. Clark Salyer. The specimens, corresponding well with topotypical ones of *variatus*, were collected in the Niangua River drainage near Marshfield, Missouri.

The intimate relationship of *P. osburni* with *P. variatus* is conclusively testified to by the agreement in many highly distinctive features of structure, form, color and habitat. They agree in having the anal fin unusually large and long, almost as large as the second dorsal fin, and the pelvic fins rather widely separated, for a species of the large group now usually thrown together as the genus *Poecilichthys*, in these respects approaching or resembling the forms of *Ulocentra*, *Hadropterus* and related genera. The two species further resemble one another in being, for their group, rather large and robust, heavy-finned fishes. In the male colors they agree in many features, notably in having bright orange vertical bars, an orange-carmine horizontal band on the lower sides anteriorly and scattered carmine spots on the pectoral fin. In both sexes, but most conspicuously in the young, the body in both species is marked by regular, oblique blackish saddles, much like those of the hog sucker *Hypentelium*. Agreement between the two species is close also in squamation, number of fin rays, etc. In correlation with their characters, both species inhabit extremely swift water, living among stones and boulders in rapids. The close relationship of *P. osburni* with *P. variatus* can scarcely be questioned.

The differences between *osburni* and *variatus* are nevertheless striking. *P. osburni* is the more terete; less arched and less elevated at the shoulders, and usually more slender (in adults the depth is contained in the standard length, 4.85 (rarely 4.55) to 5.3 times, instead of 4.3 to 5.0 (rarely 5.2) times). In *osburni* the snout is sharper and longer than in *variatus*, less bluntly decurved, and the eye is smaller; as a consequence, the eye is contained 1.2 to 1.5 times in the snout, instead of 0.9 to 1.0 times. The eye is contained in the head 4.0 to 5.2 in contrast with 3.4 to 4.05 times. The head averages smaller than in *variatus* (contained 3.7 to 4.2 as opposed to 3.4 to 4.0 times in standard length). The gill-membranes in *osburni* are less broadly united across the isthmus than are those of *variatus*, forming a sharper indentation posteriorly. The posterior part of the breast is usually scaleless in *osburni*, usually scaled in *variatus*. Numerical differences in number of scales, fin-rays and color markings are:

	P. osburni	*P. variatus*
Scales above lateral line	8 to 10, usually 9	7 or 8, usually 7
Scales along lateral line	58 to 68	50 to 58
Scales below lateral line	12 to 14, usually 13	11 to 13, usually 12
Dorsal rays	XI to XIII, 13 to 15	XI to XIII, 12 to 14, usually 13[1]
Anal soft rays	9 to 11, usually 10	9 or 10[1], usually 9
Black saddles on back	5	4
Orange bars in male	11 or 12	5 or 6

The boldest of the differences in the colors of the males involves the orange bars. The yellow area, carmine-centered, which extends from the pectoral to the anus, is encroached upon from above by the anteriormost of the orange bars in *osburni*, whereas in *variatus* this area, as also the space above it, is free from these bars, which in that species are restricted to the posterior part of the body. The dark saddles are less solid and less blackish, and more tesselated, in *osburni* than in *variatus*. The yellow blotch on the cheek of the male is much more conspicuous than in *variatus*, in which it is represented merely by a lightening of the ground color, and centers in a bright red spot which is not evident in that species.

P. osburni apparently attains a larger size than *P. variatus* by about a centimeter. Our largest specimen is 86 mm. long to caudal fin.

We now proceed with the description of the new species.

Poecilichthys osburni, new species.
Kanawha darter.

Holotype: Cat. No. 92409, Museum of Zoology, University of Michigan, is a male 75 mm. long to caudal base, collected in Stony

[1]One aberrant specimen from Ohio showed 16 soft dorsal rays and 11 soft anal rays; unconfirmed counts given in the literature give the dorsal spines as high as 14 and the anal soft rays as low as 7.

Creek, a tributary of the Greenbrier River, Pocahontas County, West Virginia, by John Addair, on June 2, 1931.

Paratypes: Seven male and female adults 60 to 86 mm. long, collected with the holotype; 2 males collected about a year previously at the same place; a female (39542, U. S. National Museum), collected many years ago by McDonald in Reed Creek, Virginia, and 7 male and female adults collected in the same stream, which is a western tributary of the New River, by Carl L. Hubbs and Edwin P. Creaser, on May 17, 1931, at a point two or three miles below Max Meadows, Virginia, at an elevation of 1,950 feet. The paratypes are deposited in the Ohio State Museum, National Museum and the Museum of Zoology, University of Michigan.

FIG. 2. *Poecilichthys osburni.* (A retouched photograph of the holotype.)

The courtesy of Mr. John Addair in allowing us to describe this darter is gratefully acknowledged.

The body is rather terete, as its greatest width is contained 1.4 times in the greatest depth. The anterior dorsal profile rises rather abruptly, though not so abruptly as in *P. variatus*, from the tip of the snout to above the eye, continuing to rise very gently to the middle of spinous dorsal, then curving gently downward to the rather deep caudal peduncle. The ventral contour approximates but is less curved than that of the dorsal. The mouth is rather small, low, subhorizontal, with included lower jaw. The teeth are small and subequal, and in rather broad bands on the jaws; there are teeth on the vomer. The premaxillary is non-protractile. The cheeks are rather conspicuously tumid. The preopercle is entire; the opercular spine is sharp. The gill-membranes meet at a somewhat acute angle, although they are still broadly joined.

The head is entirely devoid of scales (in *variatus* there are occasionally a few scales on the upper part of the opercle). The breast is also scaleless (rarely partially scaled near the ventral fins; this region is usually scaly in *variatus*). The lateral line is complete (occasionally a pore is missing).

The fins are all large. The two dorsals are joined (slightly separated in some paratypes). The highest dorsal spine is contained 1.35 times

in the highest soft ray. The pectoral fins are slightly longer than the head, and comprise 15 (rarely 14 or 16) rays, as in *variatus*. The caudal fin is subtruncate, slightly emarginate, with broadly rounded lobes.

This species is surely one of the most beautifully colored of the darters. The prevailing colors of the type and other adult males (described from fresh specimens in formaldehyde) are various shades of dark green and orange. The darkest color, a blue-black, appears on the occiput and on a vertical bar from the eye downward. The opercles are also very dark. The cheeks are largely occupied by a rhomb of bright yellow, grading into red medially. In front of the subocular bar is a similar though less conspicuous mark, obscured in high males. The middle of the snout is flushed with red. There are strong flushes of yellow on the lower surface of the head. The branchiostegal membranes are light yellow, and there is a bar of orange on either side of the midline, near the base of the lowest branchiostegals. The membrane between the mandibles is light yellow, while the rami themselves are metallic blue.

Twelve deep greenish-blue bars cross the trunk along the side of the body, not counting the large blotch at the caudal base, which together with a dark shade across the base of the caudal forms a more or less definitely triangular mark. The dark bars almost completely encircle the body behind the anus, and are rather narrowly conjoined dorsally. The twelve intervening light areas (not counting the dash of light behind the occiput), narrower and shorter than the blue bars, are deep orange. The lower third of the side of the fish, from just behind the pectoral base to near the anus, carries a brilliant horizontal blotch, grading from yellow at the edge to a brilliant orange-carmine medially; a most striking color feature, shared only with *P. variatus*. Medially the belly is pale. The breast is blackish blue between a pair of bright yellow spots which lie just below the pectoral fins.

The spinous dorsal is largely covered by a crescent of deep greenish-blue, paler on the spines than on the membranes; the basal crescent is lavender-gray, with a wedge of purplish brown on each membrane; the margin is a yellow band becoming an intense orange medially. The soft dorsal is dusky blue on the webbing, grading outward into gray within the sooty border; the gray portions of the membranes contain streaks of fire-orange; the rays themselves on their basal halves are scatteringly spotted with bright orange-red spots. The caudal is similar to the second dorsal, but the basal color is much lighter and the red spots are much more intense. The anal fin is green-blue on membranes of basal two-thirds; the rays outward are orange yellow, producing an interrupted band; the margin of the fin is milk-white anteriorly, but becomes sooty on membranes posteriorly. The pelvic is blackish green-blue, with the edges of the rays gray, and the spine and the outer border milk-white, and with some orange near border laterally. The pectoral fin is the lightest of all and the most brilliantly spotted with fire-orange; these spots are in three or four curved grayish streaks, which separate the green-blue ground color of the rays into rather definite curved bands; the outer part of the fin is yellowish on the rays.

Less developed males are not so brilliant, and the color pattern is less distinct and approaches that of the females. In that sex and in the young males the broad greenish and orange bars of the sides are much disrupted and more or less obsolescent anteriorly, and extend but little above the lateral line, where they tend to be truncated by a light greenish streak. The shoulder region and the head are colored much as in the males, but the orange bars on the branchiostegals are smaller and browner, and the orange on the cheek is diffused over the diamond-shaped whitish area. The spinous dorsal is not quite so bright as in the males, but the main band is a clearer green. The soft dorsal is also similar to that of the males, but lighter, and with rows of greenish black spots near the base. The pectoral and caudal fins are banded with dusky green and clear transparent orange. The pelvic and anal fins are cream-yellow, with whiter borders.

An outstanding feature of the species is the development of black saddles, similar to those of *P. variatus*, but less solid, more tesselated by blackened scale borders, and more numerous; there are five instead of four, the extra one being accounted for by the presence of two instead of only one on the caudal peduncle. An imperfect saddle also appears below the middle of the spinous dorsal, in a region where scarcely any darkening is evident in *variatus*. The most conspicuous saddles, as in *variatus*, are those just before the spinous dorsal, in the region between the dorsals, and below the posterior part of soft dorsal. The first saddle, fused with the first dark bar, is continued to the axil of the pectoral fin.

The young closely approach *Boleosoma* in color pattern.

Measurements and counts of holotype: Head, 3.85; depth, 5.0; eye in head, 4.6; eye in snout, 1.5; bony interorbital, 2.7 in eye; least suborbital width, 6.2 in head; upper jaw, 3.6; highest dorsal spine, 1.4 in highest dorsal soft-ray, 2.2 in head, 2.5 in first dorsal base; highest dorsal soft-ray, 1.4 in head, 1.1 in base of second dorsal; length of caudal fin, 1.5 in head; highest anal ray 1.2 in base of fin, which is contained 1.2 times in base of dorsal and 1.7 times in head; length of longest pectoral ray, 0.95 in head, of pelvic fin, 1.7. Dorsal rays, XIII–13; anal, II, 9; pectoral, 15. Scales, 8–64–13.

Variants.—Two specimens, 30 and 45 mm. long, from Big Reed Island Creek, at an elevation of 2,500 feet, just below an old mill dam in Carroll County, Virginia, collected by Hubbs and Creaser in 1931, resemble the smaller paratypes, but differ notably in having the dark markings more tesselated and disrupted, and the scales much larger, as large as in *P. variatus*. Otherwise they are very similar, and probably represent merely a local race. It is of interest that they were taken in a creek which flows into the New River almost opposite Reed Creek, where typical *osburni* was taken.

Some measurements* and counts of the two aberrant specimens follow: Head, 3.5 and 3.9; depth, 6.0 and 5.1; eye in head, 3.7 and 4.0; eye in snout, 1.0 and 1.25; dorsal rays, XI–12 and XII–13; anal rays, II, 8 and II, 9; pectoral rays, 15 in each; scales, 7–54 and 57–11.

*In comparing these measurements with those previously given, allowance must be made for the fact that these specimens are immature.

We are happy to associate with this species the name of Dr. Raymond C. Osburn of Ohio State University—long fond of the exquisite little percid fishes known as darters—in recognition of the contributions he has made, by study and encouragement, to the advancement of our knowledge of the freshwater fishes of interior North America.

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GEOGRAPHIC CONDITIONS, INFLUENCES, CONTROLS.*

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OUTLINE.

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By practice and now by definition the field of Human Geography is the relationship between the man and his environment. Many types of terms are employed to express and describe the nature of these relationships, such as conditions, influences, controls, principles and laws. Man is always among conditions. In some circumstances he is influenced by them. To these influences he responds at times by adjusting or adapting himself and his activities, at other times by modifying the conditions to suit his needs. It may be in more circumstances than we are willing to admit there is a real geographic determinism, so strong that a people cannot escape it, an absolute control. This paper reviews many terms used in the literature of the last twenty-five years, discusses and strives to evaluate them.

The works of many authors, mostly my personal friends, have been read and from their books and papers excerpts have been taken. From the nature of the case the setting could not be included with the sentence or phrase used in this paper. Desire to represent exactly what the book said has been uppermost in my mind. If misrepresentations have in the least degree entered anywhere, apologies are offered and forgiveness asked. No other way to make such a study as this could be discovered and yet the need for such a study has impressed itself upon my mind for a number of years. Therefore I have

*This paper was presented to the Annual Meeting of Association of American Geographers at the New York meeting, 1928–29.

proceeded for my own benefit and now for the benefit I trust of all of us who read the paper. Let us here take stock together of our own product and see if we can improve it in any way.

As to method of work, the various phrases used in the literature read, which express the relationship between man and his surroundings were jotted down with the reference. These terms and phrases were then grouped under several headings which now appear as headings in the paper. These brief quotations are the basis for the paper. By italicizing the significant word or phrase it is easier to pick it up quickly. Comments weave the series together and conclusions are drawn from the study.

GEOGRAPHIC CONDITIONS.

Jones and Whittlesey (1) raise three questions. (1) Are the economic activities of a country *determined* by the natural environment of the region? (2) Are they *influenced* by the environment? (3) Are they *closely related* thereto? "Determine" is a good word because every economic activity is not only influenced but is determined. If it is not determined, it could not be. The question then is, by what is it determined? It were well then to answer the first question by saying the physical environment is significant in *helping* to *determine* the economic possibilities and activities of a region. There are other factors.

If the soil, climate and topography help to determine, they do have an influence and we can answer the second question—yes. Further, if they influence the economic activities so far as to help determine what they shall be, they must be closely related. The last question then could always be answered in the affirmative, the middle one no doubt is truly answered the same way, but the first as it stands is not ready for an unqualified affirmative.

It would be fair to say that every human activity has Geographic conditions. On the same page as the questions may be found another statement. "The earth is the stage on which men live and work." But the authors do not consider the man passive to the stage, for they continue, "the broad limits within which life functions therefore are set by the natural environment. That changes but little from generation to generation even though succeeding generations make very different uses of it. But all the uses are within the limits.

Man may make and does make a choice as to how his economic life is ordered within the limits set. Sometimes he chooses wisely, sometimes not. With different knowledge and ideals, different stages of culture and needs, he chooses to make different uses."

Would it not be wise then for man to know his geography? To be as familiar as possible with the capacities and limits of his stage that he may avoid as many mistakes (bad choices) as possible?

It has been said that geography deals with the natural environment as related to man: some say as the home of man. Smith (2) would say study human activities as *affected* by the earth, rather than study parts of the earth as they *affect* human activities. Febvre (3) points out that the older historians pictured man, armies, and nations as *always* enduring and *never* acting, but joins with the others in these modern studies in believing that there are relations between man and the environment which the stage idea and that of simple conditions cannot interpret.

INFLUENCES AND RESPONSES.

If there are influences they must be met by response or resistance. Huntington and Williams (4) recognize influences. We read, "the aim is to give a clear conception of the way in which geographic conditions influence the products of a region, the capacity of the people, the direction in which their activities are turned, and the nature and extent of their business relations with other regions." Johnson (5) discusses in each chapter a great manoeuver on some front and "deals with the more striking surface features *affecting* military operations," "emphasizes the *influence* of land forms." He calls this influence a *relationship* on the previous page.

Peattie (6) says "the relations are essentially environmental *influences*." "These types of factors are the ones that *influence* the value of fields and their height limit," p. 362. "People *react* differently to the same influences during different stages of their culture or civilization," p. 6. Huntington and Cushing (7) assert "plants, animals and soils *influence* man," "man *responds* to geographic surroundings." "Man is constantly learning to overcome the influence of unfavorable circumstances and is even causing them to help him." Davis (8) speaks of *responses*, but they are not to *influences*, rather to *controls*.

Smith (9) raises the question, "How does North America *influence* man as he makes his living and lives his life upon it?" It takes the book to answer, and he is pretty consistent in sticking to the term or the spirit of the term *influence* all through.

Ridgley (10) uses the word *influence* occasionally, but leans to the other side—the *response* idea, and uses much more freely the word "*tends*." "Cities *tend* to develop wherever there is a break in transportation," p. 10. "Where coal and iron ore are in different regions the ore *tends* to go to the coal," p. 123. He seems to follow Cooley (11) in this, for Cooley says, "population and wealth *tend* to collect wherever there is a break in transportation." This term becomes monotonous but has the advantage of indicating the direction of the influence. Fairbanks (12) does not use the word *influence*, but *responses* and *relationships*. He says, "*relationships* is the unifying idea at the root of all true geography," "Method of interpretation is the essential thing," "Pupils can reason out life *responses* to physical environment in other parts of the world after knowing similar *relations* in the home region."

Miss Newbigin (13) says, "the necessity for finding the metals best suited to his use . . . has always *influenced* the movements and the settlements of men." While on the same page she speaks of the "distribution of minerals being of great importance in *determining* the distribution of man," she has no spirit of geographic determinism, but recognizes the relationships as influences. In another book she says, "The significance of (geography) lies not in separate facts . . . but in that they have to be considered in their inter-relations. . . . Students cannot acquire too soon the habit of linking the great facts of climate and relief with the life of man." She adds, p. 19, "Human geography may be defined as the study of the . . . *action* and *reaction* between man and nature."

RELATIONS AND INTER-RELATIONSHIPS.

Miller and Parkins (15), p. XII, reads, "Geography as relationships between natural environment and life," "Geographic environment does not explain everything," "Probably no one thing (cause or factor) explains any particular phenomenon in life." Here as in many references "relation" is used instead of influence, but it is about as non-commital. It may be a relation expressed in man's response or adjustment to the

conditions or it may be a relation expressed in man's modification of the environment. It is indefinite.

Jefferson (16) makes it clear in a number of illustrations that the same place has called forth very different *responses* from different people at successive times, thus illustrating interrelations and at the same time the fact that the mind of man has something to do with the nature of the response. For example, he points out that the American Indian in the Great Lakes region was essentially a fisher and hunter, the Frenchman was a hunter and a missionary, the mixed Europeans later were general farmers, raised corn and built cities, but he does not tell us the nature of the relationship. Was it helpful to man, or otherwise? Obviously each man used what he wanted in the way he wanted to; but neither Jefferson nor Vidal de la Blache, who used the same illustration, points out how the region helped the man, presented obstacles to him and spurred him on to his characteristic activity. One must not be satisfied with simply discovering influences, or relations. He should show how the conditions are related to the man and how the man is related to the conditions.

Again on p. 32 the same author finds the North Central Plains of Europe supporting lumbermen in the middle ages after a reign of huntsmen and fur gatherers, then producing great crops of wheat, oats, potatoes and rye for the agriculturists. While all this continues in the plains, man has recently tapped the mountains for mineral wealth and now the plains support great industrial cities. But in all the page the only word stating the nature of any relationship is "*prevents*," referring to mountains not high enough to keep out roads and railroads. In this case one can easily infer that the relationship in these latter days is considered to be quite *advantageous* to man.

In her preface Newbigin (14) reads, "the relation between groups of men and the character of the lands in which they have established themselves." This is the general statement introducing the later studies where the nature of the relations is very adroitly disclosed.

Brunhes (17) says, "Human Geography is a study of the relationships between human activities and the phenomena of Physical Geography . . . soil, climate, circulation of water, vegetation and animal life on the one hand, human establishments, ways of travel, cultivation, breeding, exploitation

of natural resources on the other are united by bonds of causality more or less apparent by connections more or less close. . . . " Again, "Human phenomena which *inscribe* themselves on the soil, and which *modify* nature at the same time they *are modified* or brought about by nature." These quotations are both from the preface. They are the general statements, the broad undisturbed generalizations. In the body of the book where specific regions or types of houses are discussed the relations are much more specifically expressed.

Jones and Bryan (18), p. 3, assert, "we must grasp the significance of this interrelation of man and his environment," but they speedily slip far beyond the zone of influence into the field of determinism and control to be discussed below.

Unstead and Taylor (19) start well. In the preface we read, "The treatment is as far as possible causal and no facts are given without explanation." This is certainly a recognition of relationship in geography. In the text, facts of physical geography are often very well explained, but it is quite difficult to find real geographic material in the human relations, even through large sections of the book. Facts of environment are stated, then facts of ontography, but the nature of the relation is too often left to inference.

Febvre (3), p. 361, is clear cut. "What are the *relations* between human societies of today and their present geographical environment? That is the fundamental problem and the only one which human geography sets itself." And one has but to turn to his inspiring chapter on Communications to discover how lucidly he interprets the relations into "*forbidding*," "*attractive*," "*inhospitable*," "*hindering*" and "*favorable*" relations. He rarely leaves one in any doubt in specific cases what the real nature of the relationship is.

CONTROLS AND GEOGRAPHIC DETERMINISM.

In working over the literature for this point of view surprises have been found. It is no more than fair to some authors to say that were they writing today they probably would couch their ideas in different words. It is also true that *controls* and *dominations* are in degrees of intensity.

Johnson (5), p. III, "To emphasize this interesting relationship between inanimate nature and the Science of War" is followed by, p. 1, "The violation of Belgian neutrality was predetermined by events which took place in Western Europe

several million years ago. . . . nature was fashioning the scenery which was not merely to serve as the setting for the European drama, but was, in fact, to guide the currents of play into blackest tragedy." "If . . . Germany would not have been tempted to commit . . . The surface configuration of Western Europe is the key to events in the theater of war." This author in succeeding paragraphs gives due credit to ambitions, ideals, and covetousness and thereby suggests that the trouble was not wholly in the topography.

Ratzel is perhaps the strongest advocate of Geographic determinism, but his work and that of some of his predecessors may be excused in part by the lack of knowledge in the science. No quotations will be made.

Vidal de la Blache (20) says, p. 17, "It most often happens, with slight obstinate exceptions, that the *sovereign* influence of environment has *forced* all Europeans into similar occupations and customs." "Some societies have long been part of the environment, but others are in process of formation, continuing to recruit members and to be modified day by day. Upon such in spite of all they can do, surrounding conditions leave their impress, and in Australia, at the Cape, or in America these people are slowly becoming saturated with the influences of the regions where their destinies are to unfold." Again on pp. 29–30, "Increase of population always encounters serious obstacles, many of them insuperable; . . . some of them are superabundance of vegetation and insect life or insufficiency of moisture or heat." Perhaps this is not meant for absolute determinism and should simply be dated to save it. 'Insuperable' today is a challenge and may not be at all insuperable tomorrow. In fact this geographer, p. 20, gives us a redeeming picture. "The task of colonization—glory of our age—would be only a sham if nature set definite rigid boundaries instead of leaving a margin for the work of transformation or separation which it is man's power to perform." This introduces another point of view less absolute, p. 19: "Man is at once both active and passive," "Relation takes the form of man's transforming the environment."

Brunhes (21), p. 58, writes, "According as human groups are placed in this or that geographic setting they are *led* or *impelled* to grow certain crops, here horses, there palms and rice, here cattle and there sheep; and each type of activity brings about its own type of social organization." Perhaps

he meant more of a *control* existed than is suggested by the translation "led," but if so it would hardly be in keeping with his other interpretations.

Miller and Parkins (15), p. 55, reads, " . . . future national leadership in air and sea may be *determined* by the possession of fuel oil. . . . " This factor may help to determine.

But Jones and Bryan (18) use the word *control* even more than these American and French authors. In preface, p. VII, "author's aim has been to indicate the nature of the controlling geographic facts." p. V, "The peopling of the continent by Europeans began so early as to suffer a very complete measure of geographical control." "In every stage of development of these new lands (America) the shape and size, the winds and currents, of the Atlantic ocean have been *controlling* factors and it is to our purpose to study the nature and operation of these *controls*."—p. 3.

"Geographic factors which were *limiting* Spanish so largely to Southern Mexico." "The *dominating* factors here are very simple."—p. 31. "Position of early French settlements, in North America, were *largely controlled* by the nature of the St. Lawrence and Mississippi rivers."—p. 42. "Geographic conditions obtaining in New France very *largely controlled* the nature of settlement."—pp. 54–5. "In spite of . . . (several items mentioned) they (New England colonists) followed a mode of economic development *almost completely controlled* by their geographic environment."—p. 66.

Davis (22) wrote, "The fact that Celtic is still spoken in rough, distant, or isolated parts of Great Britain because of their roughness, distance and isolation is a local example of an important class of relations between controls and responses." This quotation is given as an illustration of the "third position which would treat ontography as thoroughly as physiography and would search for all the geographical relations of physiographic *controls* and ontographic *responses*." Subsequently the author records that he has adopted this third position.

Huntington and Williams (4) have several paragraph heads in *control* terms. p. 19, "How relief *controls* the nature of the products." p. 98, "How physical conditions *determine* the detailed location of trade routes." Also sentences in the paragraphs under the headings, "After general location has been *determined* by centers of human activity, details are *determined* by physical conditions," and "Since relief has a *dominating*

influence upon transportation it seems to stand second only to climate in its *influence* upon man's activities."—p. 42. "Factors which *limit* the distribution of the more complex forms of manufacture."—p. 212.

Von Engeln (22) writes, "The *dominance of environmental control* has not been generally accepted as an adequate foundation for a complete theory of history." "The book is written not so much to show that human organization and development *have been determined* by geographic conditions as to insist that in future they *should* be." Smith (2), p. 4, tells us, "To an extent little appreciated the environment *makes* the race. It is a common mistake of the historian to give the idea that people have certain qualities inherently. It is much more correct to say that primitive or savage peoples are primitive or savage because of the niggardliness or peculiarities of nature's gifts. The environment . . . has given the qualities." But the strongest statement of control, the best example to date is the testimony of a lecturer on problems arising from the great war. He said, "'but Germany *had* to do it, her geography *impelled* her! It was necessity! necessity!! necessity!!!" This was not said in any heated debate or flight of oratory, but in a quiet conversation in my laboratory while maps were being selected for his use.

Bowman (23), p. 3, gives a suggestion on this point of *control*. "Thus plants are thought to have a certain physiologic plasticity or power of self-regulation that tends to adjust them to a new environment, a feature that goes far in explaining the *absence* of *rigid control* of physiographic conditions over forest distributions, although an *approximate control* is often manifested." And Von Engeln (22), p. VI, finds a something somewhat akin in man. "History in sum is the record of man endowed with a free will, refusing at first to conform to his environment and hence being buffeted about by nature until he comes to terms with her."

Jones and Whittlesey (1), p. 4, "Man may make and does make a choice as to how his economic life is ordered." p. 3, "Such knowledge (geographic) is inherently interesting. It is also essential if wise use is to be made of the natural possibilities of any given area." And Febvre (3) adds, pp. 76–77, "Geographers are now striving to bring into prominence the initiative and mobility of man. They regard the land as 'powerful agents,' " but as Newbigin (14) in her preface says, the new

geography methods are by some considered objectionable "in that they take too little account of human intelligence and ingenuity, of man's powers to modify his environment and of evading what is sometimes loosely called *geographical control.*"

Peattie (6) adds, p. 4, "Changing environment is not so important as the changing state of the culture of people," "The varying effects are not so much the result of the changing of the tools which make the impression as of alterations in the human material upon which the tools place their mark. Peoples react differently to the same influences during different stages of their culture or civilization;" p. 6, "We must study human phenomena as we study a body in motion." Brunhes calls it the "principle of activity." Neither do men always "choose the most favorable climate in which to live."—p. 11.

If one says, "The same conditions have the same results," one must remember that conditions include the human mind and its power both of choice and of adjustment.

Jones and Bryan (18), p. 3, state it thus: "We must finally see man gaining a wider freedom through a fuller knowledge;" and Miller and Parkins (15), p. 31, meet Smith above with the suggestion that "Not all racial stocks produce the same results in the same or similar environment." People and countries have grown up together and modified each other until 'stock' means something. And further, p. 33, "Adjustments are not permanent but changing. Absolutely permanent adjustments will never occur with a progressive people."

METHODS OF EXPRESSING RELATIONS.

If we fall into troubles then in expressing the interrelations of men and places by using such terms as conditions, controls, and determinants or if the terms relation and influence are insufficient, how can we interpret our data? Suggestions here, too, can be obtained from the literature.

Jones (24) clears himself in his preface, p. V, "A portrayal of the various factors and conditions *influencing* the trade expansion of the several republics;" then "Special attention has been given to the physical factors *favoring* or *discouraging* production and movement of a commodity." The direct statement with a relative clause may be used. p. 32, "Possibilities for commercial expansion in South America are great because . . . (7–8 reasons)." p. 33–4, "Exports are mainly raw industrial materials because . . . (4–5 reasons)." Hunt-

ington and Williams (4), p. 98, "Just as the water has advantages over land for transportation, so have plains an advantage over mountains." These *advantages* are also well worked out in Huntington and Cushing (7), pp. 114–15 and 133–34.

Jefferson (16) uses the term advantageous, too, in discussing relations. Pp. 39–40, he raises the question, what *stimulates* one city rather than another to grow to the million size. He illustrates relations also by "transformations that help each people (French and English) to settle into its environment while *shaping* it to its own peculiar characteristics."—p. 6.

Miller and Parkins (15), p. 5, "As population increases, and it increases most rapidly where economic (geographic) *advantages* associated with the lands are most abundant." Again, p. 31, "peoples' *opportunities* depend upon size of area, resources and competition."

Peattie (6) uses advantage, and benefits in places, but he strings along the facts of physical and human elements with no sort of connecting phrases to suggest the nature of the relationship. His work is largely descriptive; p. 78, "Today colonies with modern sanitation can maintain healthful conditions in most places in tropical forests. The well organized permanent settlement has little to fear."

Rocheleau (25) finds a few words in which to express the relationships among which are "*causes*," p. 1, "*make necessary*," p. 4, "*disadvantages*," p. 153, but his ontography is about all he has. He speeds on in an interesting way with facts of human occupation, production, building and commerce with rarely a word of explanation, though he recognizes in his opening pages that there are geographical reasons for differences in population densities and in the supply of things to meet man's needs. It is unfortunate to call such a book 'Geography.' Fairbanks (12) is superior in that it has many facts of both environment and ontography, but it does not make many direct statements of relationship.

Two terms, *adjustment* and *adaptation*, are used some. They may be applied either to man himself or to his processes. The words are used in a similar technical sense by Spalding (26) in his admirable study of two phases of plant geography. "Adaptations to the environment are structural, adjustments are physiological."—p. 140. The plants have made many changes in these two categories to meet the conditions in which they find themselves. Vidal Blache (20), p. 9, quotes Haeckel

as follows: Ecology is the science of "*correlations* between all organisms living together, and their *adaptations* to their surroundings." Since Ecology is plant or animal geography these words have good standing and may well be used in expressing relationships in human geography. To be sure a figurative meaning will be necessary in many cases, though of course they can be used of men exactly as of plants in a limited way.

Peattie (6), p. 13, says, "men learn to adapt themselves to new climates;" and of the English soldier in India, "Here the most careful and clever *adaptation* to climatic environment has taken place;" "the reduction of (alcoholic) drinking is another example of adaptation." Men become physiologically *adjusted* to high altitudes and rare air through generations of living in the high plateaus of Bolivia and Tibet. Smith (9) p. 5, "Politics are largely the attempts of men to *adjust* themselves to industrial and economic factors." Perhaps *adapt* would be the better word here.

While man is adapting and adjusting to the conditions in which he finds himself he is also modifying the conditions. Brunhes' statement of this relationship has been quoted. Woeikof (27) says, "man has control chiefly over movable bodies, particularly the mantle rock, or in places where the mantle is thick. He not only changes the inorganic but the organic." Man's modification of conditions is very striking in his health and sanitation changes in low latitudes and in his modification of the water supply and distribution in arid lands. The term is often used by Marsh (28) even in his title, "The Earth as *modified* by man." A different use of the term is found in Huntington and Cushing (7), p. 11, where we read, "Every religion is *modified* by its surroundings, especially those of its birthplace." 'Colored' would be a much better word here for the relation. Their word would apply to changes made in a religion and its terminology when it is transferred from one kind of a place to another.

This part of the paper would not be complete without special reference to a characteristic of geographic interpretation found in some books—the use of words which qualify the influence, relation or response. Every shade of meaning and degree of response may be found. On two or three pages of Huntington and Cushing (7) the following phrases are found: "Man *responds* to geographic surroundings," "Local circum-

stances *alter* man's *responses* to his higher needs," "Europe's *fortunate* size," "North America *hampered* by size and relief," "*Difficulties* of the farmer in rugged regions," "Seasonal variations *hinder* the use of water power."

Miss Semple (29) uses this list of terms and phrases expressive of geographic relationships all on one page. The Upheaved Carpathian Mountains *divided, diverted, guided, checked.* The Alps *retarded, delayed, obstructed; admitted* invaders, who arrived with *weakened* power, *prolonged the life* of the empire, *facilitated.* River worn valleys *led* to passes, by which traders *crossed.* Today *going* is *easier,* but Alps *collect* toll in higher freight rates, and more coal consumed. Formerly these mountains *barred* the weak and timid. Today they *bar* the poor, and *forbid* transit to all merchandise that cannot pay. Rockies *excluded* all but the strong-limbed and strong-hearted, today *exclude* coal and iron of Colorado from California and *check* the movement of laborers to California, thus *tighten the grip* of labor unions on Pacific coast industries.

Further on, p. 189, large area *misleads* primitive folk, *offers* to advanced people *freest* conditions for their development. A wide territory . . . *affords* most *favorable* conditions. Numerical growth was *rapid,* both by natural increase *reflecting* abundant food, and by accessions *attracted* from the home countries. These examples suggest ways for the careful, thoughtful student to express the relationship without repetition, and with description enough of the relation that the reader can catch its nature.

STRENGTH OF MAN'S ATTACHMENT TO ENVIRONMENT.

On several occasions students have watched the progress of men in their freeing of themselves from the restrictions of environment and have wondered if man would not soon become wholly independent of it. When man overcomes latitude and survives a long, cold journey to the pole by sledge, then boat, dirigible and speedy plane, what more cares he for cold and distance? When he climbs to the top of Mount Everest, what limits do altitude put upon him? When he builds a Panama canal and maintains it with a better health and efficiency schedule than in many parts of the temperate zone, why say he is hampered by the tropics? Isn't he really loosening up all his relations to the environment and even shaking them off?

Perhaps to answer one should go far back in man's history and see how closely he was then related, before coming to final conclusions. Newbigin (14) points out, p. 5, that "in attempting interpretation of past events and historical developments in order to establish correlations between physical and human elements as of ancient dates, there should be a full knowledge of both the conditions and the development." Peattie (6) cautions, p. 10, against broad generalizations and interpretations that go far back where man cannot know. He cites such examples as the effort to explain the sunken neck and high shoulders of the Central Asiatics, the narrow eye slits of the desert people, the dark skins of many peoples within the tropics. It is probably true that we know too little about geographic relations among early races to really answer the question by such comparisons.

May there not be another avenue of approach? Examine Peary or Byrd in his home environment to find what relations he holds to the environment, then examine again on his polar journey and see if he has less relations or more. Note how long he studied and experimented to make enough connections and harmonies, adjustments and modifications to be able to complete his journey.

Count up the relations and contacts with environment that a man in Ohio makes to be able to work in good health, and then note what a wide range of connections and relations the Canal Zone worker has. Not only does he eat and drink, sleep and work there under all the local conditions, but he meets disease with science and medicine brought from elsewhere, reads and thinks in a foreign language and with a foreign outlook, draws a large percent of his food and equipment from distant lands, mines, mills and farms, and even obtains his job and pay from the profits of enterprises thousands of miles away.

It seems probable that every successful man in the temperate zone has closer relations, adjustments and harmonies with his environment than the less successful. The same is true of the nation. If it is true of men in the temperate zone it is to be more and more true of the successful colonizer of the intertropic and polar zones.

Before men could fly, their relations with the air were very limited and their knowledge of it was more restricted. Man surely is establishing closer relations with his environment

in his industry, commerce and trade, science, medicine, agriculture, mining and probably every other occupation. Conquests of oceans, lands, air and life continually add to man's relationships. Not until we know all about the earth, air, sky and life will we cease to extend our relationships to our environment.

SUMMARY AND CONCLUSIONS.

While in many general statements it is quite necessary or, to say the least, very convenient to use such undistributed terms as *influence* and *relation* in Geography, it is very desirable to use terms expressing accurately and clearly the nature of the relationship or influence. Such terms should make it clear to the reader that the *relation* is helpful or detrimental, advantageous or otherwise, and further the degree and kind of advantage can usually be stated. The terms control and demand probably should but rarely be used of geographic factors, but in every case geographers can further the cause by using such terms as really convey the quality, nature and extent of the influence.

It is well to recognize the larger and closer contacts man makes with his geographic conditions as he learns the laws operating in his surroundings. Complete knowledge of all geographic conditions, and of all laws governing all conditions, followed by complete adjustment of every man and occupation to every element of these conditions wherever man makes a contact, would put the individual and the race in a most happy and prosperous harmony, and would insure that humanity was making the best use of all parts of the earth.

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Discussion

Miss E. C. Semple made the valued point that environments are of many kinds and belong to many relams, while geographic conditions are always in the field of the geographer. Hence it is more exact and less cumbersome to speak of geographic facts and conditions than to use the longer more general term environmental factors or elements.

CALCIFIED WOOD FOUND IN UPLAND SAND NEAR CINCINNATI.*

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INTRODUCTION.

The specimens of calcified wood here reported are of interest for three reasons. Because of the pronounced crystallization habit of calcite, cell structure is usually obliterated by the crystal growth. For this reason, the replacement of wood structure by calcite has seldom been reported.[1], [2]. A case of partial replacement of wood by dolomite is reported by S. F. Adams.[3] In the petrified wood here noted, the wood structure is imperfectly preserved and fragmentary, but sufficiently clear for identification as a gymnosperm.

Another point of interest is the probable age of the wood. The sand in which it is found may be of late Tertiary age as inferred by Dr. Leverett,[4] but it seems more likely to be of pre-Illinoian Pleistocene age. Calcified wood as recent as the Pleistocene has not been reported, as far as known to the writer.

In addition, the position of the water-laid sand is interesting. It occurs on the upland a mile and a half south of the Ohio River and a mile and a half west of the valley rim of the Licking River at an elevation of 390′ to 400′ above the present water level.

PHYSICAL CHARACTER OF WOOD FRAGMENTS.

The wood specimens are of two sizes. The smaller pieces are 3 or 4 inches long and about one inch in diameter (Fig. 1), and the larger are 8 to 12 inches long and 4 to 6 inches in diameter. (Fig. 2). The smaller are calcified throughout with a brown limonite stain along the annual rings and on the outside surface, which resembles bark. The wood fragments

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*Presented in part before the Ohio Academy of Science, April 19, 1930.

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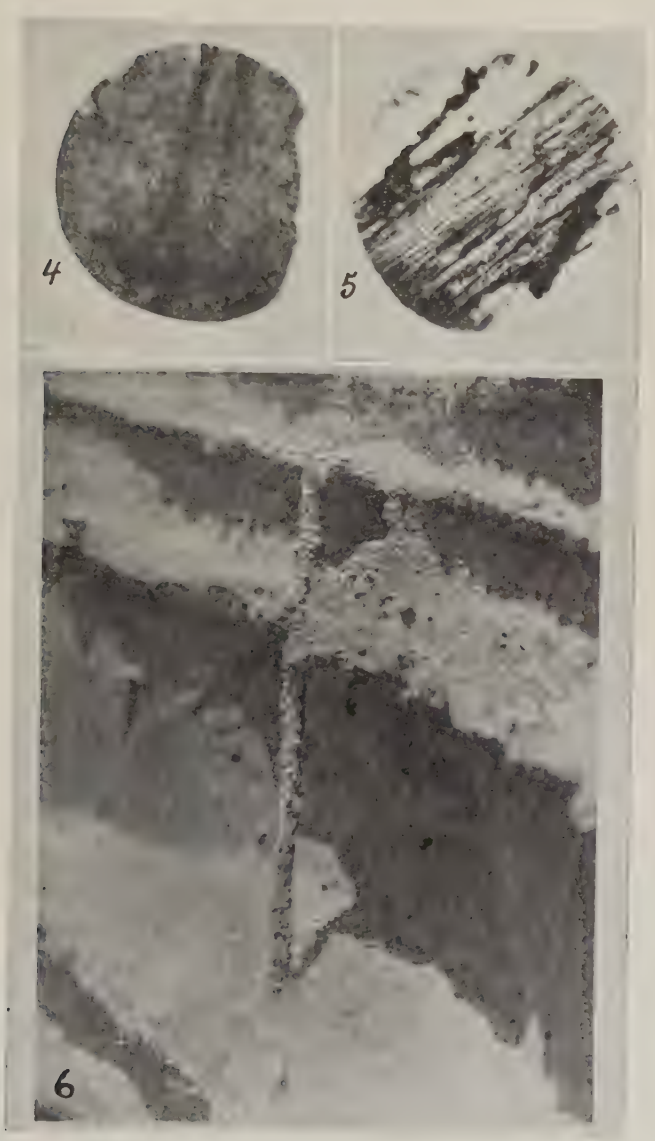
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are in part hidden by cemented sand clinging in concretionary form. The smaller specimens occur in generally horizontal position projecting from the deposit. The larger pieces are merely shells of limonite with the central portion missing altogether except where broken-off branches project, and these are filled with calcite.

The large shells appear to stand in upright position, and one which had been thrown aside by the workmen and was not seen in place, stands at right angles to a flat, cemented layer which one would expect to be approximately horizontal. (Fig. 3).

There is no cell structure preserved in the larger specimens, so they are of interest chiefly because the relative position of the two kinds of fossils suggests that the smaller are branches of the larger, especially since the latter have broken branches of about the same cross section as the small pieces. The fossilization in the smaller specimens is so imperfect that it cannot be said whether we are dealing with stems or roots. It seems unlikely that they are modern roots which have penetrated from the present surface which is 12 or 15 feet above and separated from the sand by a heavy layer of calcareous and limonitic cement.

MICROSCOPIC CHARACTERS.

From what seemed the best specimen of wood, fourteen thin sections have been made for examination under the microscope. These include five cross-sections, five tangential sections, and four radial sections. The cell structure as exhibited in the cross sections is very imperfect, but seems to show (Fig. 4) that the wood is without the pores or vessels which all angiosperms show. This would identify the wood as that of a gymnosperm. In radial section the tracheids are not clear enough to make certain whether the pits are bordered as in all gymnosperms or not. In tangential section the ends of the medullary rays are clear in several cases and these are undoubtedly uniseriate (Fig. 5) which is characteristic of many gymnosperms, though not diagnostic.

Closer than this, the identification seems impossible from the sections at hand. Before the specimen was ground, both Dr. Walter Bucher, of the Geology Department of the University of Cincinnati, and Dr. John Hoskins, of the Botany Depart-

ment, thought the general appearance of the wood was like that of a cedar. Nothing in the microscopic examination is contrary to this, though a definite identification is not possible.

DEPOSIT IN WHICH THE WOOD WAS FOUND.

The fragments of wood were found in an 8- to 10-foot deposit of very fine sand on the upland a little more than one mile south of Covington, Kentucky at an elevation of approximately 820′ A. T. The sand is very fine with scattered tiny chert pebbles, partly cross-bedded, with bedding planes outlined in brown, and very calcareous throughout. In this fine material occur abundant concretions of random shapes and enormous proportions, in addition to the many specimens of calcified wood, themselves forming nucleii of concretions. The sand is being removed for sale as molder's sand in aluminum and brass work, its per cent of calcium carbonate being too high for use in molding iron.

At the top of the bed of sand is a cemented zone 8 to 10 inches thick which is largely calcium carbonate, but also partly limonite. In some places, the cement is quite solid throughout and in places it is made up of fragmentary beds separated by unconsolidated material. These consolidated layers separate the lower deposit from a succession of coarser water-laid beds above, in places calcareous and in places leached, which appear to be composed of succeeding layers of greatly decomposed gravels and clean sand, with one thin band of bowlder clay. The reason for the band of cemented material seems clear from the fact that the sand below grades into a foot or more of the finest silt toward the top, immediately beneath the present zone of cementation. This is followed above by the coarser, pebbly sand and gravel. When the deposit was first excavated there appeared in the gravel one band of bowlder clay about six inches thick with ten or fifteen feet exposed laterally. In the absence of any other bowlder clay in any other exposure in the neighborhood, the band of ice-laid material was interpreted as due to a floated ice block. This has been supported by the entire disappearance of the band of till since the excavation has been cut farther back, and by its failure to appear in a new excavation in the same deposit at a little distance from the first digging.

DEPOSIT OF DECOMPOSED GRAVEL.

At a higher level, up to 900′, but apparently continuous with this deposit, is a greatly decomposed gravel, dark brown and streaked with black stains, which is leached to a depth of 18 to 20 feet so that it does not effervesce with weak hydrochloric acid. This deposit has abundant pebbles up to three inches in diameter, though mostly small, and many are so decomposed that they crumble to powder in one's fingers. The pebbles are largely of chert and quartz, though many of quartzite, granite, gneiss and basalt were also found. It is the granite and gneiss pebbles which are so greatly decomposed and these give off strongly the odor of kaolin. The pebbles lie in a matrix of clayey material, the result, probably, of their own decomposition and not like bowlder clay. Besides, there are no bowlders. The material is decomposed gravel, not bowlder clay. The deposit is being cut away and screened, for use as molder's sand in molding iron. This deposit seems to correlate with an exposure at the same level on the Dixie Highway about half a mile distant and three quarters of a mile northeast of Ft. Mitchell. Here the material is largely sand showing horizontal bedding planes.

From the top of the leached gravel to the base of the sand in which the calcified wood was found, there is a difference in elevation of 75 feet as measured with the aneroid, and the two kinds of material appear to be a continuous deposit down the slope of the hill. The sand is said to rest on clay below, but this is not exposed.

PRE-GLACIAL EROSION SURFACES.

Glacial sand and gravel on the upland 390′ to 465′ or 470′ above the present drainage (Licking River at 430′ two miles east, Ohio River at 430′ one and a half miles northwest) points, of course, to a time in the Pleistocene when the drainage of the region was at that level. It is believed, however, that the level on which the deposit now rests was at the time of deposition at a lower altitude. That there are high-level benches in this vicinity representing old valley floors antedating the present rejuvenated streams will be discussed in a later paper. Of these, the old 800′–820′ erosin surface, the highest of such benches in this vicinity, is represented by prominent shoulders, clearly to be seen in the field. The ridge southwest of Covington

has on both sides ridge-like shoulders extending out toward the valleys, which are remnants of this old bench along the old drainage lines. These fragments of the same level present on the map the characteristic pattern of a dissected terrace. The sand where the wood was found rests on one of these shoulders.

The 800′–820′ valley floor is succeeded at about 700′–720′ by another level which also extends tongues of land out toward the valleys, less prominently in this exact location than elsewhere in the Cincinnati quadrangles. There are reasons for believing that both these benches probably existed above the drainage in early Pleistocene time, but that the present trenching of the rivers has taken place since, as stated by Dr. Leverett.[5] Such benches, if they did exist, would be apt to receive and hold a river-laid deposit at any time of unusual flooding.

AGE AND ORIGIN OF DEPOSITS.

To review the evidence for reconstructing the history: The sand where the wood fragments were found is very fine, grading into a powdery silt at the top and it has no pebbles except tiny ones of chert. This is separated from the gravel and sand above by the zone of calcareous cement. The gravel is without any doubt of glacial origin. The events interpreted from these facts might well have been as follows: As the ice from the north advanced, the Licking, or some other north-flowing stream of this region, was dammed, causing it to deposit sand followed by silt as the current slackened to none at all. This was followed by an invasion of outwash from the ice front. If the upright position of the tree trunks be more than accidental, they may have been buried in place as the flooding waters encroached on the higher levels. The outwash material at 900′ marks the relative level to which the glacial waters rose.

If this break in the kind of material at the cemented layers can be interpreted as given above, the sand and the included calcified wood would be of Pleistocene age. The glacial material above the river sand and clay would have furnished the lime for the cement which has been localized by the contact with silt, as well as for the concretions and the calcified wood.

As to the age more exactly. The upper deposit of decomposed gravel—not immediately in contact with the sand and silt—but higher up the slope (880′-900′), as mentioned above,

[5]Leverett, Frank, loc. cit.

is leached to a depth of 18 to 20 feet, whereas gravel of Illinoian age exposed at the surface at Mariemont just north of the Ohio River is leached only 8 to 10 feet below the surface. This would seem to signify that the age of the gravel is pre-Illinoian as given by Dr. Leverett.[6] Dr. Leverett, however, speaks of the material on this ridge as drift and till. Only one narrow band of till, later removed by excavation, has been seen by the writer. The whole ridge as far as exposures furnish data would seem to be covered with outwash of a pre-Illinoian glacier rather than by till.

OTHER CALCIFICATIONS IN PLEISTOCENE SAND.

In Cincinnati in a valley deposit of accepted Illinoian age, shells of two tree trunks or large branches were found at the level of a cemented zone between outwash below and bowlder clay above. These were in appearance like the larger specimens found in Kentucky and seem to the eye unlikely to show any cell structure under the microscope. Their position was horizontal. The exposure is on Este Avenue just north of Ivorydale.

Another mode of calcification was observed in the same deposit in very fine sand at a place where the zone of cement was missing between the sand below and bowlder clay above. Rootlets, evidently modern, had penetrated from the surface and when exposed in the excavation for sand showed a white encrustation of lime. (Fig. 6). Also fault planes, evidently due to slumping when the very fine sand was wet, were accentuated by planes of calcareous deposit projecting slightly beyond the steep slope of sand. Many rootlets had also taken advantage of the space along the fault planes and these, too, were encrusted with lime. So calcification of a sort seems to require no great length of time.

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[6]Leverett, Frank, loc. cit.

MICROFOSSILS IN AN ARKANSAS PEAT AND THEIR SIGNIFICANCE.*

PAUL B. SEARS AND GLENN C. COUCH.

OBJECT OF THE INVESTIGATION.

This is an extension of a series of studies by one of the authors and his associates (1) on fossil pollen in peats of the North Central States. The purpose of such studies has been to secure information concerning the general trend of climate in postglacial time, as an aid in interpreting present vegetation.

These previous studies have indicated that postglacial climate has been largely of continental type, cool at first and later warm. Separating the cool dry from the warm dry period there appears to have been a definite although brief period of greater humidity, relative if not absolute. A similar increase of humidity is believed to have occurred recently.

In the present study diatom remains, as well as pollen, have been considered. This was necessitated by the destruction of all carbonaceous matter in the upper layers by the fire which led to the discovery of the deposit.

The recent character of the deposit permits a study of the latter portion only of postglacial climate, but the results so far as they go, are consistent with those obtained elsewhere. We estimate the record to extend back at least 1800 years—basing this figure on the age of cypress stumps and a conventional figure of three centuries per foot of peat. This estimate seems quite conservative.

MATERIAL.

Dark Hollow is a former lake bed at the northern edge of the Arkansas River terrace, 1 mile northeast of North Little Rock, Arkansas. The area is now drained by a large ditch and under cultivation, but its former character is shown by huge cypress logs. One stump still in position has a diameter of 4–5 feet above the buttresses. The existence of peat here was revealed by a subterranean fire early in 1931. The State Geological Survey thereupon sent specimens of this peat to

*Contribution from the Botanical Laboratory, Univ. of Oklahoma, NS No. 14.

Professor Albert W. Giles to whom the writer is indebted for knowledge of the deposit.

Collections were made in March, 1931, after the fire had ceased. The peat was then overlain by about eighteen inches of ash and slag and was itself so hard that the use of a borer was impracticable. Specimens were secured by cutting back steps at the edge of the machine-made ditch. About four feet of peat lay below the ash, all very clayey. This clay increased in stiffness downward until a layer of heavy blue clay without fossils was reached. Samples were taken at intervals of six inches.

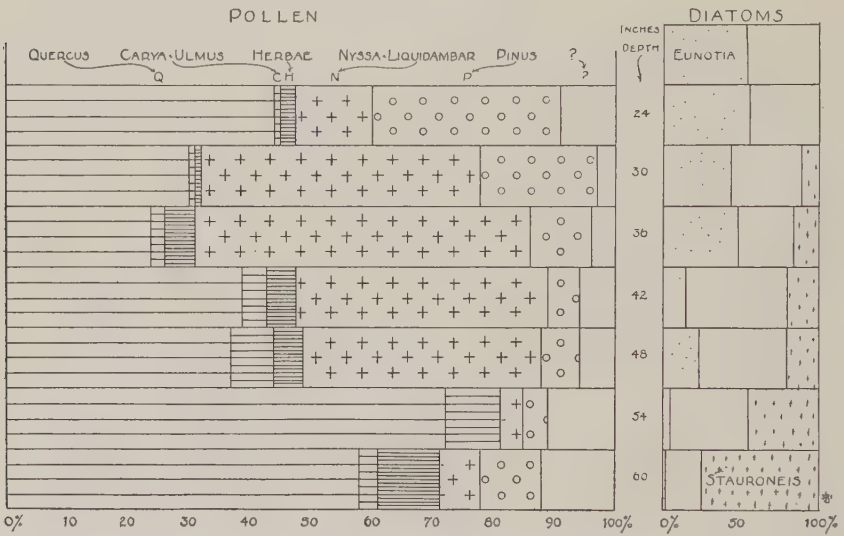

FIG. 1. Diagram showing changing percentages of fossil pollen and of fossil diatoms at successive depths in Dark Hollow peat near Little Rock, Arkansas.

PROCEDURE AND RESULTS.

To permit study of diatoms, slides were prepared by nitric acid treatment in addition to those prepared with KOH for pollen study. Samples were centrifuged and mounted in glycerine jelly as in preceding studies (2). Slides were prepared by Miss Mabel Larcomb who also assisted with the pollen counts. All diatom counts were made by the second author.

The results, expressed as percentages, are given in Tables I and II, and summarized graphically in Fig. 1. Pollen of *Quercus* predominates up to the 48″ level. The 48″ to 30″ levels inclusive show a strong admixture of *Nyssa* pollen.

Pinus forms less than 10% of the whole until the 30″ level is reached, from there on increasing rapidly toward the top where with oak it is relatively abundant. Herbs (amaranths, composites, grasses) are most abundant at 60″. *Carya*, while never abundant is most nearly so at the 54″ level. Pollen

TABLE I.

PERCENTAGES OF FOSSIL POLLEN IN DARK HOLLOW (ARK.) PEAT.

Depth in Inches	Amaranthus, etc.	Carya	Compositae	Gramineae	Liquadambar	Nyssa	Pinus	Quercus	Ulmus	Unknown	Pollen Frequency
24	.....	.01	.03	.....	.01	.11	.31	.44	.....	.09	277
30	.....	.01	.01	.....	.02	.44	.19	.30	.....	.03	645
36	.....	.01	.05	.....	.04	.51	.10	.24	.01	.04	231
42	.....	.04	.05	.....	.01	.40	.05	.39	.....	.06	49
48	.01	.05	.04	.....	.06	.33	.06	.37	.02	.06	93
54	.....	.09	.....	.....	.04	.....	.04	.72	.....	.11	62
60	.01	.03	.06	.03	.....	.07	.10	.58	.....	.12	16

frequency (PF) decreases from values above 250 per sq. cm. of slide at the top to 16 at the 60″ level. In the blue clay below that level both diatoms and pollen are absent or exceedingly rare.

TABLE II.

PERCENTAGES OF FOSSIL DIATOMS IN DARK HOLLOW (ARK.) PEAT.

Depth in Inches	Eunotia sp.	Melosira varians	Pinnularia lignitica	Nitzchia sp.	Stauroneis sp.	Pinnularia nobilis	Eunotia robusta	Cymbella sp.	Navicula amphiloba	Pinnularia major
18	.54	.17	.05	.05	.....	.04	.....	.....	.....	.26
24	.55	.....	.09	.25	.....	.....	.....	.....	.....	.12
30	.43	.07	.07	.....	.11	.....	.05	.08	.07	.11
36	.48	.05	.02	.....	.16	.....	.....	.01	.09	.19
42	.14	.....	.02	.04	.20	.06	.....	.04	.04	.45
48	.23	.04	.09	.04	.21	.06	.....	.03	.....	.29
54	.05	.....	.....	.....	.45	.36	.05	.05	.....	.05
60	.01	.....	.03	.....	.76	.01	.....	.....	.....	.18

No pollen of *Taxodium* was certainly identified, although the area has been evidently occupied by cypress for at least 800 or 1000 years. This agrees with the experience of Lewis and Cocke (3) in the study of the Dismal Swamp, and illustrates one of the sources of difficulty in pollen analysis.

Among the diatoms *Eunotia* sp. shows a striking increase toward the top while *Stauroneis* sp. shows an equally striking decrease from the bottom upward. *Pinnularia major* appears in fluctuating percentages throughout, while *Nitschia* and *Melosira* are more abundant toward the top.

INTERPRETATION OF RESULTS.

There is good reason to believe that the upper 18″ of burned material represents peat essentially like that in the 24″ layer. Not only the general similarity of diatoms is evidence of this, but also the fact that the 24″ layer consists largely of pine and oak—the characteristic vegetation of the region at present. Air dry peat from the 24″ level when burned in an electric muffle shows a linear shrinkage of 20% indicating that the 18″ of ash represents at least 22″ of original peat. Settling to a depth of several inches has occurred over the burned area.

The task of climatic interpretation would of course be greatly simplified if specific instead of generic distinctions of pollen could be made. Such distinctions will be possible when our knowledge of pollen taxonomy is extended and refined (4) and have already been employed in certain cases (5) (6) (7). But their use in any case will involve an enormous increase of labor, not justifiable as a practical measure until other means have been utilized so far as possible.

The very low pollen frequency just above the clay, together with the abundance of black humified globules suggests that the lower part of this peat was deposited under conditions so dry or so exposed that extensive oxidation occurred. The steady increase of pollen frequency upward might be due to a number of causes, but is at least not inconsistent with other evidence indicating a corresponding increase in climate humidity.

The most striking feature of the pollen profile is the small number of genera involved. *Juglans, Acer, Fagus, Fraxinus,* all of which preserve well and are characteristic of the more humid hardwood forest east of Arkansas are here missing. This suggests that no part of the column represents deposit from an adjacent vegetation any richer than that of the present in Arkansas. On the other hand if one goes west from Arkansas today the predominant upland forest of *Pinus echinata, P. taeda, Quercus* sp., *Carya glabra et* sp. gives way to one in which the pines are absent and oaks, notably *Q. marylandica* and *Q. stellata,* with some *Carya,* are dominant. The Dark Hollow

pollen profile exhibits just such a change from top to bottom. This warrants the inference that the 60″ and 54″ strata were deposited under climatic conditions approaching those of central or eastern Oklahoma, i.e. notably drier than the present climate of Central Arkansas, and that the upper strata accumulated under conditions of increasing humidity.

Nyssa, so conspicuous above the oak and below the oak-pine strata is prominent today in both the upland and swamp vegetation of Arkansas and eastern Oklahoma, but does not appear in abundance so far west as do the oaks. Whether its prominence at intermediate levels indicates an increase in swamp areas or an enrichment of the upland vegetation, or both, cannot be determined. In either case the indications favor a recent increase in climatic humidity consistent with the idea of the preceding paragraph.

Thornthwaite (8) in his studies of climates and soil types in Oklahoma has observed that present climatic boundaries do not correspond with the appropriate soil limits, but lie west of them. This too is quite consistent with our evidence of a recent increase in humidity, for the effect of climate on soil requires time to register.

Finally it is interesting and possibly significant to note that the diatom *Stauroneis*, so prominent at the base of the profile, is today abundant in central Oklahoma while *Eunotia* is rare there but abundant eastward. However, this statement is based on a limited number of collections.

SUMMARY AND CONCLUSIONS.

The circumstances just discussed, to-wit: the succession from an impoverished oak-hickory fossil flora of low pollen frequency through a considerable *Nyssa* stage to an oak-southern-pine fossil flora of high pollen frequency, with a corresponding shift from *Stauroneis* to *Eunotia* in the diatom fossils are interpreted as indicating a recent increase in climatic humidity for central Arkansas. This agrees with earlier findings in the North Central States, and is of interest because the Dark Hollow peat lies far south of the glacial boundary.

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NOTES AND COMMENT.

It will be noticed by reference to the inside page of front cover that the editorial staff has been reorganized and augmented and that a wider distribution throughout the state is provided for. The cordial co-operation promised by members of the staff will, we feel sure, result in a greater range of selection for articles and, we trust, for a greater usefulness to science workers generally.

H. O.

NOTICE.

IMPORTANT TO MEMBERS OF THE OHIO ACADEMY OF SCIENCE.

Under the action taken by the Academy at Oxford, last April, it is necessary that all nominations to fellowship in the Academy must be in the hands of the Secretary at least 60 days before the annual meeting at which they are to be voted on. If, as has been the custom the past several years, the annual meeting is held near Easter, which comes next year on March 27, the nominations must be filed in January. A suitable form on which to make nominations can be secured from the Secretary.

The Executive Committee of the Ohio Academy of Science has authorized, subject of course to ratification by the Academy, the formation of a new section, a *Section of Geography*, with Dr. Eugene Van Cleef, of the Geography Department, Ohio State University, as the temporary Vice President. Persons interested in this section should communicate with Doctor Van Cleef.

W. H. ALEXANDER, *Secretary*.